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United States
Department of
Agriculture

Forest
Service

Intermountain
Region

Ogden, Utah

# — PROJECT SPARKEY —

# A STRATEGIC WILDFIRE MONITORING PACKAGE USING AVHRR SATELLITE DATA AND GIS

-P-R-O-J-E-C-T- -S-P-A-R-K-E-Y-

# A STRATEGIC WILDFIRE MONITORING PACKAGE

# USING AVHRR SATELLITE DATA AND GIS

Intermountain Region
Region 4
USDA Forest Service

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prepared by

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*About the Cover*

The cover image is the area of interested monitored in this report. It represents a 1500x1500 pixel area centered over the NW corner of Utah. Image is from AVHRR NOAA-11 on August 14, 1994. Bands 1 2 3 are displayed in a blue, green, red sequence. Clouds are seen in blue. The Great Salt Lake is near the Center, San Francisco Bay is in lower left. Note the fires burning in eastern Oregon and central Idaho.

OUTLINE

-P-R-O-J-E-C-T- -S-P-A-R-K-E-Y-

A STRATEGIC WILDFIRE MONITORING PACKAGE USING AVHRR SATELLITES AND GIS

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# A STRATEGIC WILDFIRE MONITORING PACKAGE USING AVHRR SATELLITES AND GIS

## I. INTRODUCTION

### A. Summary and Overview

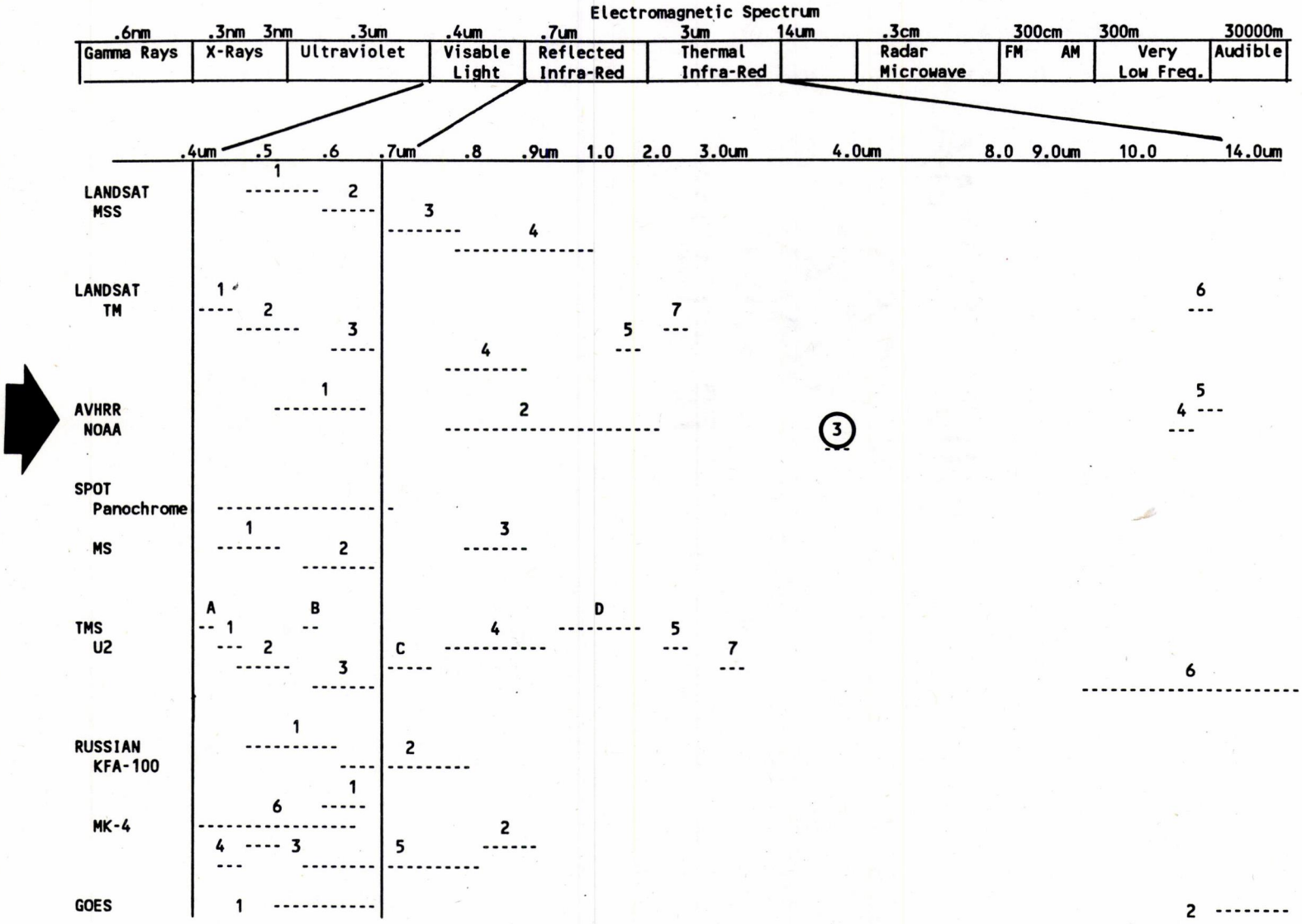
During August and September of 1994, wildfire status was monitored in Forest Service Regions One and Four for 42 consecutive days using AVHRR satellite data. Down-linked from a commercial receiving station, satellite data was received in real time over a phone modem between San Diego, California and Ogden, Utah. In all, over 125 individual satellite passes were retrieved from the receiving facilities to the Ogden Utah site. The digital data was processed, enhanced, interpreted, and distributed over the Forest Service X400 dataline and/or in hard copy format, typically within one and one-half hours of a satellite pass. Between three to four satellite passes were processed daily depending upon cloud cover and satellite angle (nadir) to specific fire locations.

The potential for using AVHRR Satellites to monitor wildfires is mentioned in several literature references, however, this application is one of the first quantitative applications of a daily series of AVHRR data to monitor fires in real time. The 1994 fire season in the Intermountain Region (Region 4) was the largest since 1930 when the Forest Service began keeping accurate records. The use of AVHRR satellite data is a tool for a broad area overview of wildfire status. Its primary use is strategic and not generally tactical for individual fire management. In general, the target customers were Regional Foresters, fire staff officers, fire coordination centers and information centers. In this current application, only limited use was made of the platform for Regional wildfire detection and tactical (actual fire site) applications, even though fire as small as 10 to 15 acres in size were commonly observed. The system did provide some valuable tactical intelligence during initial 1994 blow-up situations when smoke obscured areas and overhead-support organizations were not yet in place.

The AVHRR (Tyros) system, operated by NOAA, is a five frequency or sensor system with one frequency in the visible spectrum (band 1), one in the near IR spectrum (band 2), a mid-IR frequency (band 3), and two frequencies in the thermal spectrum (bands 4 and 5). Generally, for fire monitoring, band 3 was used exclusively. Data resolution of individual pixels or grid cells is 1.1 kilometer by 1.1 kilometer (or approximately 200 acres). However, due to high fire temperatures influencing an overall pixel, fires of 10 to 15 acres in size could be detected, as were commercial heat plumes from point sources such as smelters and smoke stacks. Tyros 11 and 12 were the satellite platforms used during the 1994 fire season. In raw 10 bit format, Band 3 data for each pixel is recorded in degrees Celsius (0 to 100 degrees). Refer to figure 1 for a band frequency comparison of common satellite platforms.

Processing was accomplished through a three staged program involving (1) a commercial receiving station (Seaspace of San Diego, Ca.) to capture satellite data (analog to digital); (2) retrieval, analysis, and enhancement of digital data with Seaspace's Terra Scan image analysis software, and (3) vectorization, mapping, and distribution on a Arc-Info GIS system. This latter system has been bundled into an automated package, using a graphic user interface (GUI), for transport and migration to other computer systems operating on RISC technology.

Figure 1 - COMMON SATELLITE PLATFORM BAND FREQUENCIES



B. Operations

(1) Satellite Receiving Facilities

The Seaspace TeraScan HRPT Antenna Server acquires, archives, processes, and displays HRPT telemetry data from the Tyros-N polar orbiting weather satellite sensors including:

AHVRR - 1 km resolution multispectrall imagery
TOVS - vertical sounding of atmospheric temperature and moisture
ARGOS - earth location and data relay from small transmitters mounted on buoys, balloons, wildlife, etc.

All data from all instruments are acquired and stored at their fullest resolution, however, for the purpose of fire monitoring, only AVHRR data was down-loaded. The Antenna Server operates in a stand-alone fashion, or linked via Local Area Network (LAN) to other computer systems. The antenna has a 1.2 meter tracking dish coupled with a workstation computer. The system software includes processing of AVHRR data for precision navigation, radiometric calibration, etc., and also includes algorithms for cloud-screened surface albedo, temperature, atmospheric aerosol optical depth over water surfaces, and vegetation index.

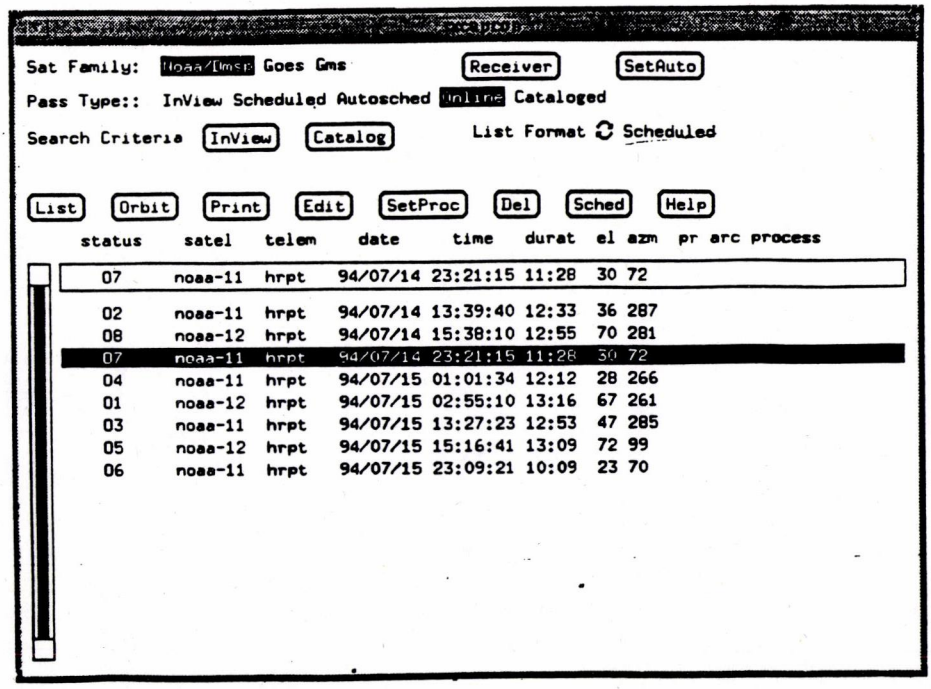
The part of the system in San Diego (1) provided maps of satellite passes, predicted the satellite overflight time, angle, and height (2) allowed clipping out of an area of interest from a global scene (a 1500x1500 kilometer area with the center near the northwest corner of Utah), (3) allowed the retrieval of all 5 bands of data or individual bands, (4) allowed the retrieval of either 10 bit or 8 bit data (8 bit data was used to keep compatibility with our existing GIS systems). Data was then retrieved to Ogden Utah via telephone modem. Refer to figure 2.

(2) TerraScan Image Processing (Ogden, Utah)

The Terrascan software provided at the Ogden Utah site included a suite of general image processing and display functions including (1) image display overlain with lakes, states boundaries, latitude-longitude grid, and contours (Federal land ownership was added as an overlay during this fire monitoring process), (2) image color enhancement (contrast stretch), pan & zoom, animation, and annotation, (3) interpolation to standard map projections, math, statistics, filtering, and sampling. Refer to image 1.

Once data was received, initial geo-registration was done to an Albers Equal Area projection, using automated routines in the software. This included (1) a general registration program using the center point and corners of the Area of Interest, and (2) a visual navigation routine for final correlation of the raster image with cartographic feature data. Using these routines, the fires could be geo-reference to approximately two to three pixels of actual ground location.

Figure 2 - Screen View of Satellite Schedule and Path Swath from Satellite Receiving Site in San Diego, Ca.


Sat Family: Noaa/Tmsn Goes Gms
Receiver
SetAuto
Pass Type:: InView Scheduled Autosched Online Cataloged
Search Criteria InView Catalog
List Format Scheduled
List Orbit Print Edit SetProc Del Sched Help
status satel telem date time durat el azm pr arc process
07 noaa-11 hrpt 94/07/14 23:21:15 11:28 30 72
02 noaa-11 hrpt 94/07/14 13:39:40 12:33 36 287
08 noaa-12 hrpt 94/07/14 15:38:10 12:55 70 281
07 noaa-11 hrpt 94/07/14 23:21:15 11:28 30 72
04 noaa-11 hrpt 94/07/15 01:01:34 12:12 28 266
01 noaa-12 hrpt 94/07/15 02:55:10 13:16 67 261
03 noaa-11 hrpt 94/07/15 13:27:23 12:53 47 285
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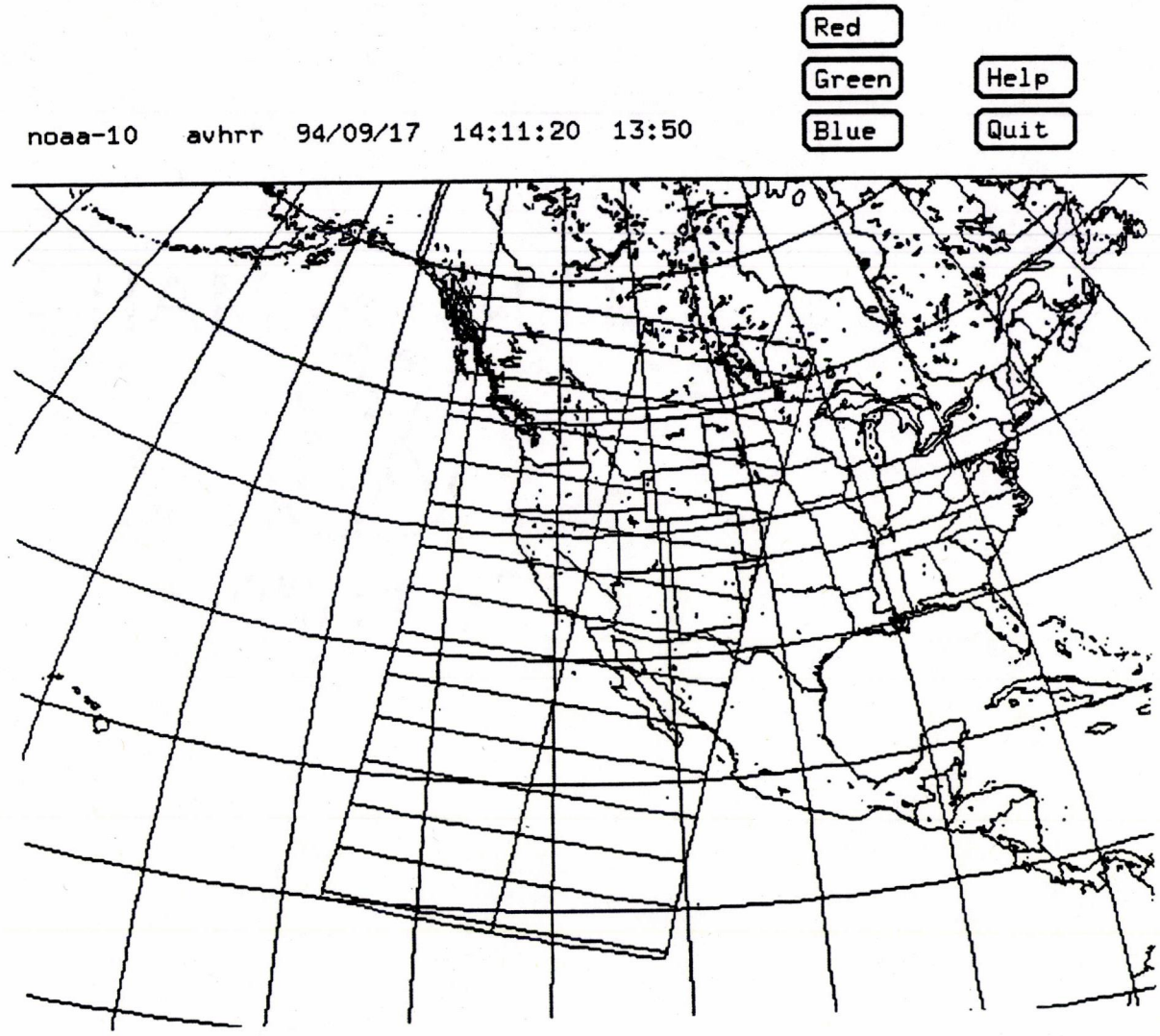
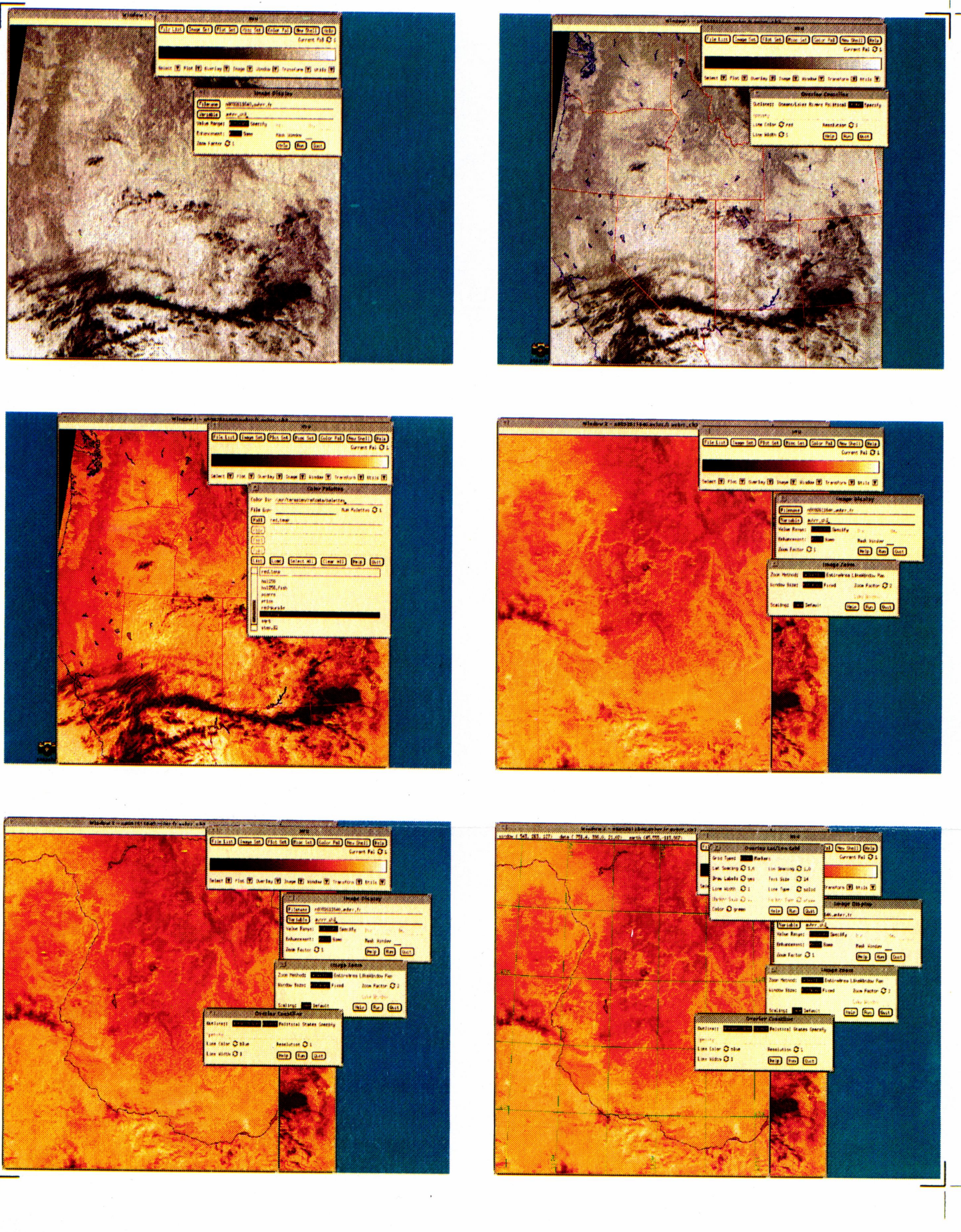


Image 1 - Overview of TerraScan Graphic User Interface.

Upper Left - Geo-corrected image of Western United States.
Upper Right - Adding State Lines for Reference.
Middle Left - Color Enhancement (Contrast Stretch).
Middle right - Zoom in to Area of Interest (Idaho Complexes).
Lower Left - Adding Major Rivers and Lakes Overlay.
Lower Right - Superimposing Latitude-Longitude Grid for Final Display.



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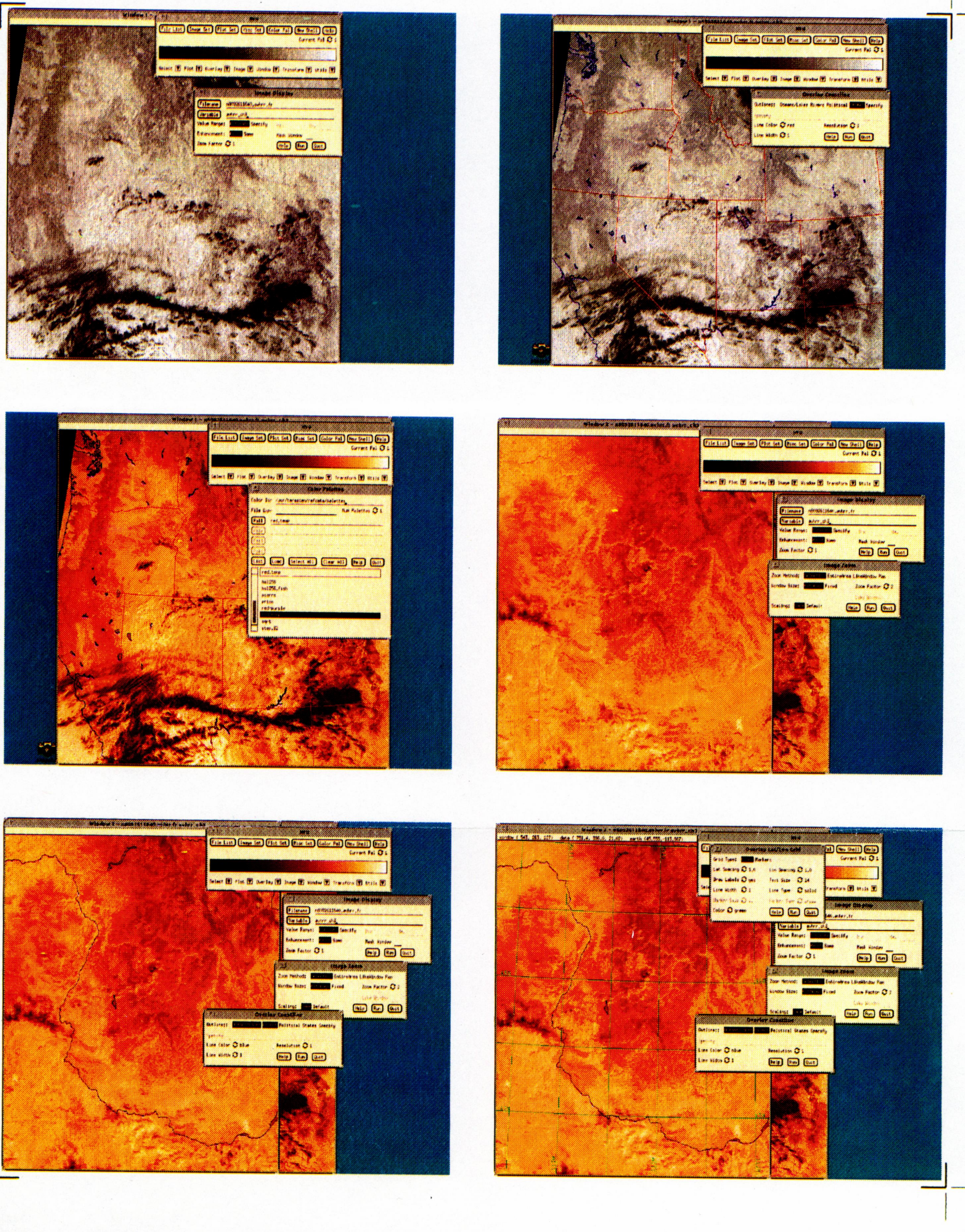


Then, fire complex windows were cutout of the western US coverage, the image was enhanced in color to contrast fire areas, overlays illustrating major rivers, land ownership, and longitude-latitude grids with annotations, were added. The unenhanced raster full image, together with all raster enhanced and annotated window images were then moved by Local Area Network (LAN) to an Arc-Info GIS workstation. Following formatting in GIS, all these same raster windows were also moved via LAN to the Region's Data General computer system which allowed other Forest Service sites (Forests, Region 1, Fire Coordination Centers, etc.) to retrieve immediate fire intelligence data.

(3) GIS Processing Ogden, Utah

GIS processing involved moving the raster data via local area network to a Arc-Info GIS environment. The GIS environment operated from a Graphic User Interface (GUI) developed by Region Four, to automate GIS processes and facilitate its operation. Once moved and the naming conventions established, pre-processed and raw raster images followed two separate pathways: (a) the pre-processed images received image headers and then were stored in both the executive browse library (automated viewing for managers) and the Regional Four Data General system for external unit retrieval of the data. Hard copy color prints were distributed. And (b) raw raster images received in the GIS from the TerraScan processing were processed to vectorize high temperature pixels. This involved several steps:

Step 1 - Re-registration of the image to an Albers Equal Area Projection. Unfortunately, the image formats between TerraScan and Arc-Info do not support the transfer of geo-reference data. Therefore, a program was developed in TerraScan to read the X-Y coordinates of the upper left corner of the image. These coordinates were then used in Arc-Info to "project" the image back to a geo-referenced status (the pixel dimensions and number of rows and columns of data in the image remained constant in both formats).

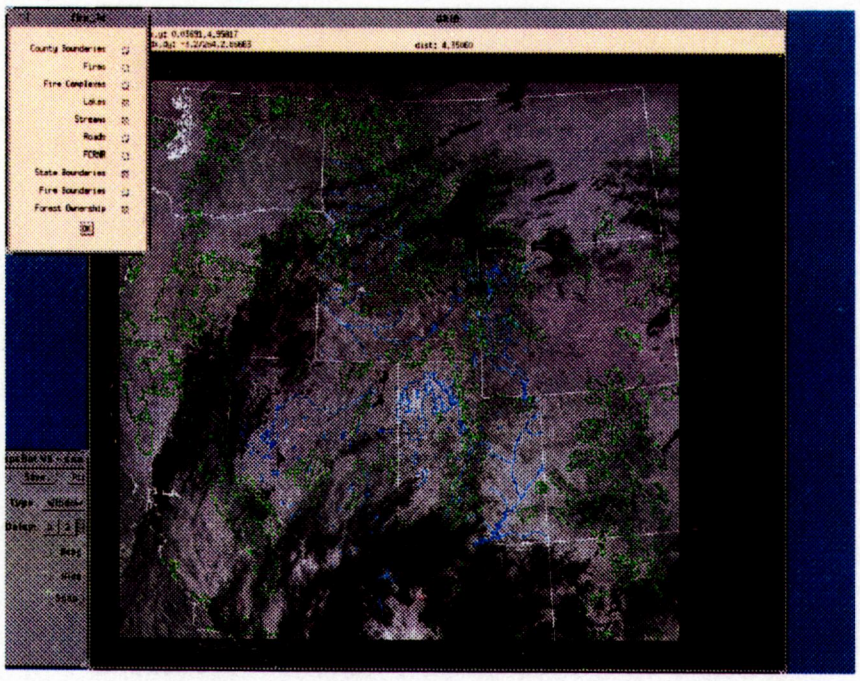
Step 2 - A visual navigation routine was used for final correlation of the raster image with cartographic feature data. Like the routines in TerraScan, with the GIS routines, the fires could be geo-reference to approximately two to three pixels.

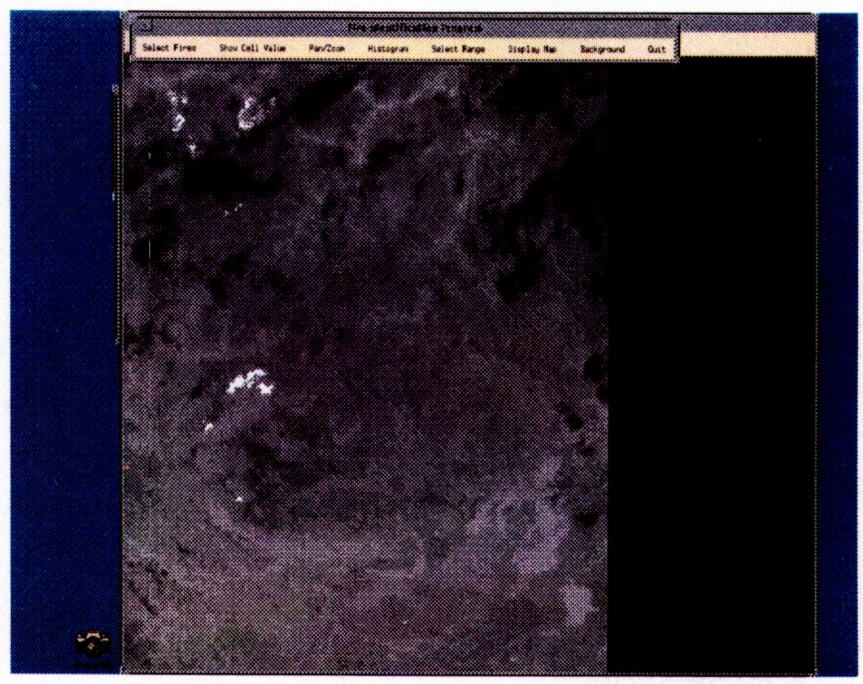
Step 3 - Display of image and selection of pixel numeric range to represent fire temperatures. This isolated the individual high thermal reading areas or fires on the image.

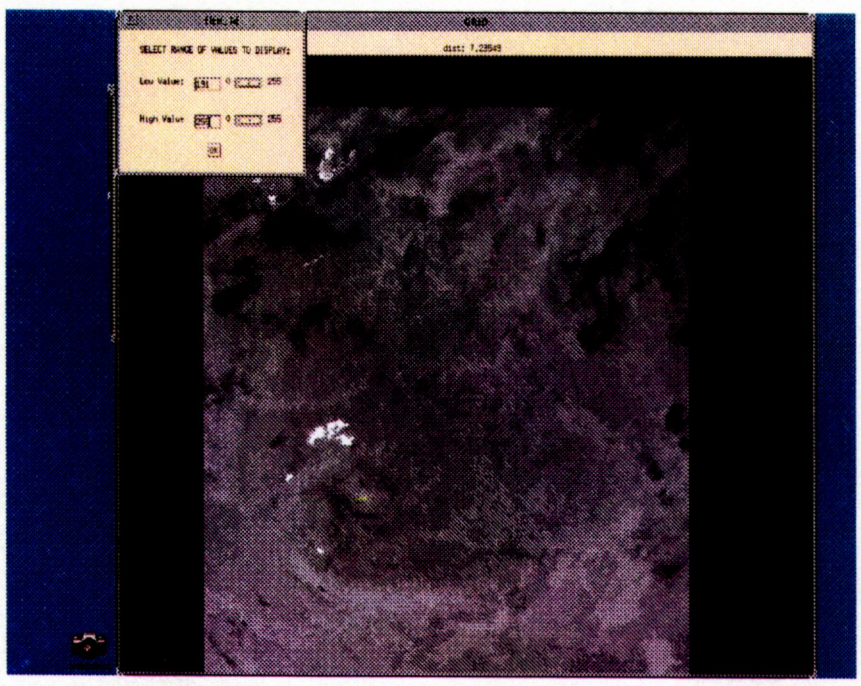
Step 4 - Selection of fire areas to be vectorized by selection of individual pixel or groups of pixels, entering the fire name to be stored in the data base, and then executing the vectorization process. Refer to Image 2.

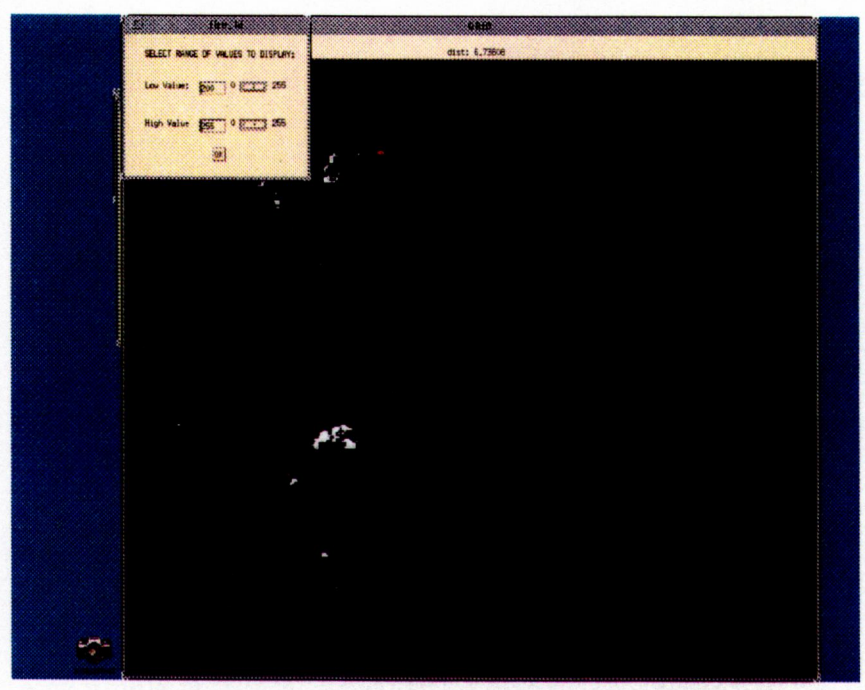
Step 5 - Once the individual fires were vectorized, daily and/or cumulative plot maps were processed for the entire area of interest. Because of map accuracy considerations, output plots and supporting cartographic feature data scale was 1/2,500,000. The plots were then stored in the Data General system. Hard copy plots were also generated for distribution. Hardcopy size was 33" x 51". Refer to Figure 3.

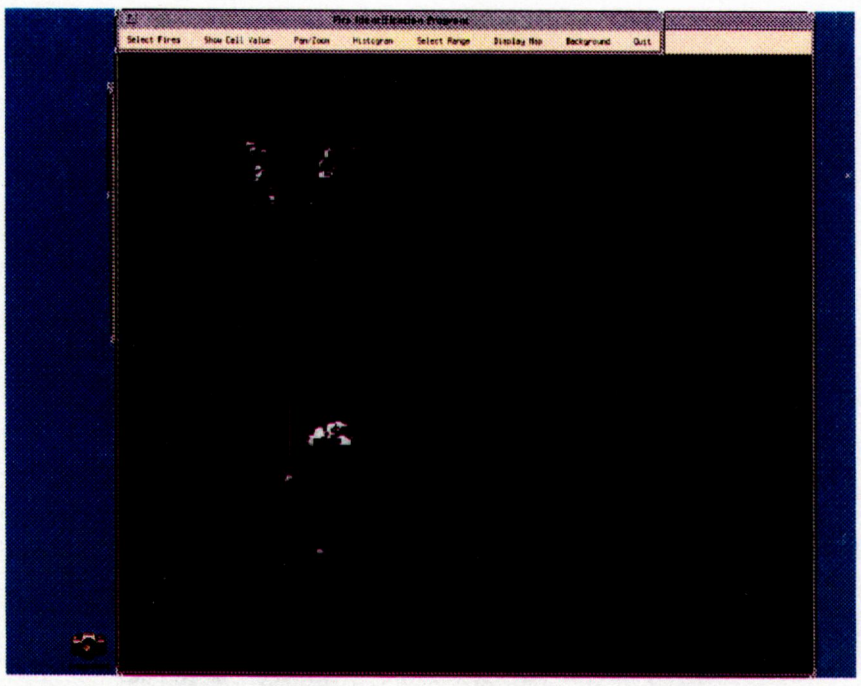
Image 2 - Overview of GIS Vectoriztion Graphic User Interface; Upper Left - Raster Image Overlain with Forest Boundaries, Upper Right - Zooming in on Idaho Fire Complexes. Middle Left - Selecting Digital Range of Thermal Temperatures, Middle right - Displaying Selected Range to Isolate Fires, Lower Left - Selecting Individual Fires to Vectorize, Lower Right - Naming Fire Complexes for Inclusion in GIS Database.

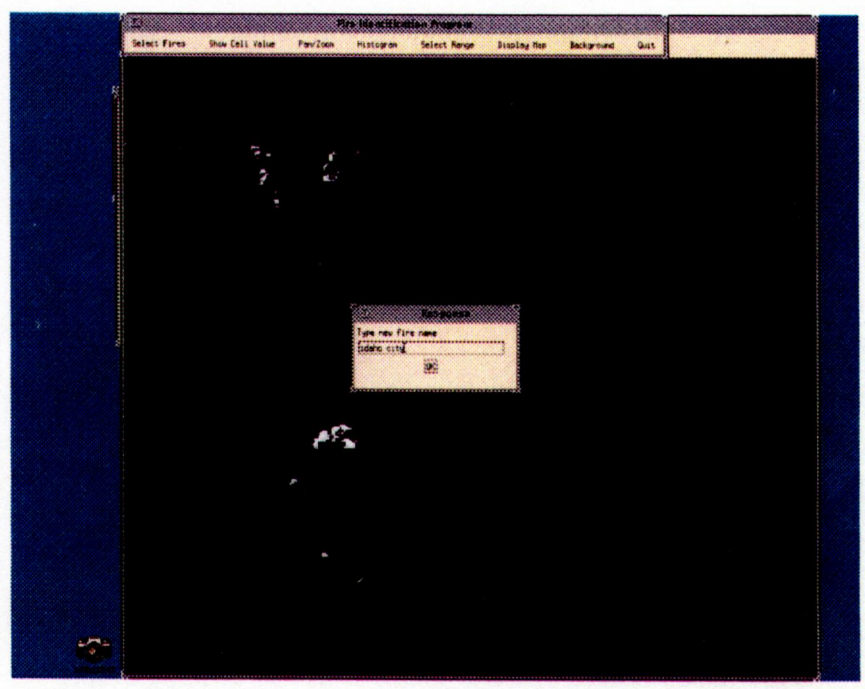


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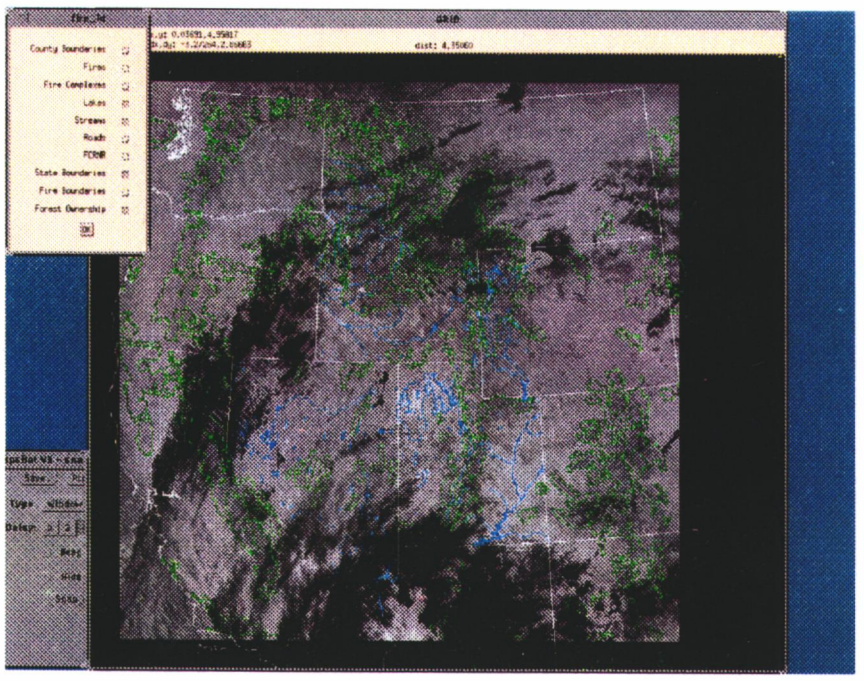
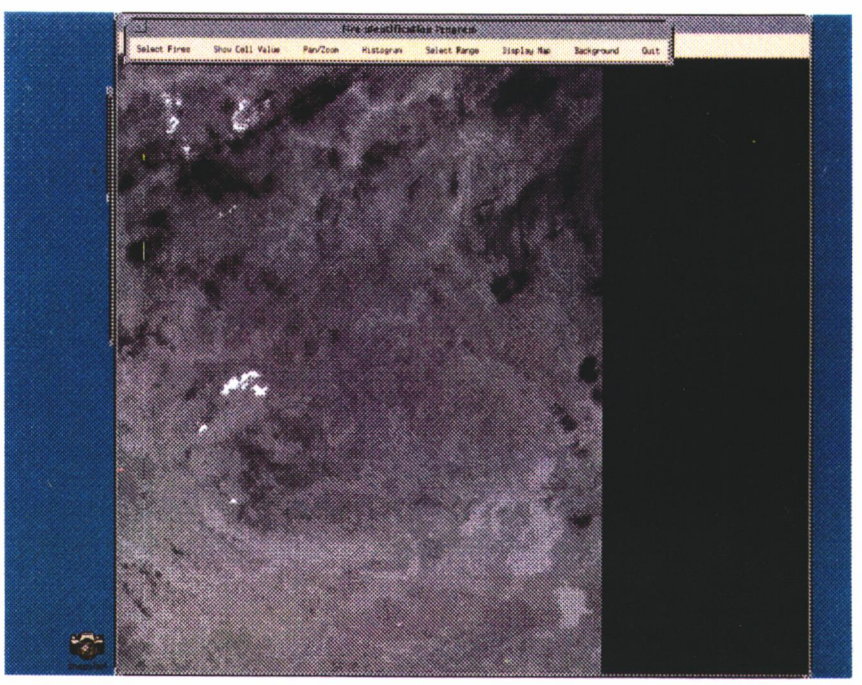
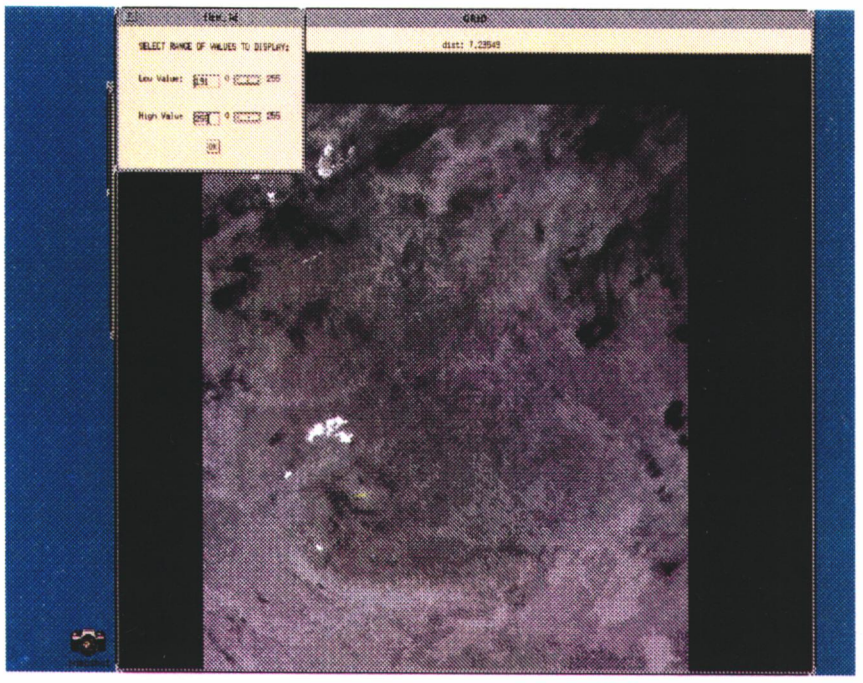
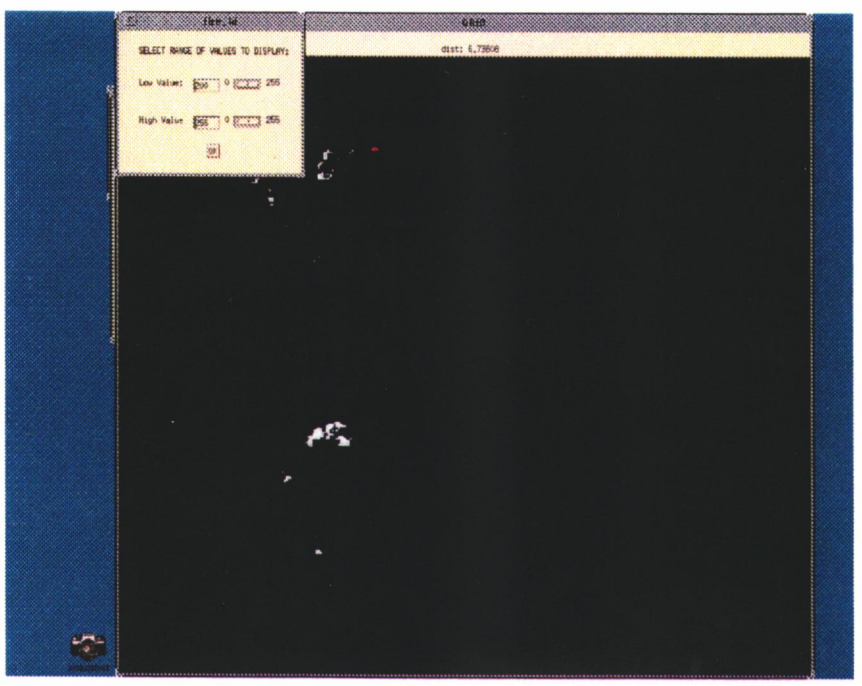
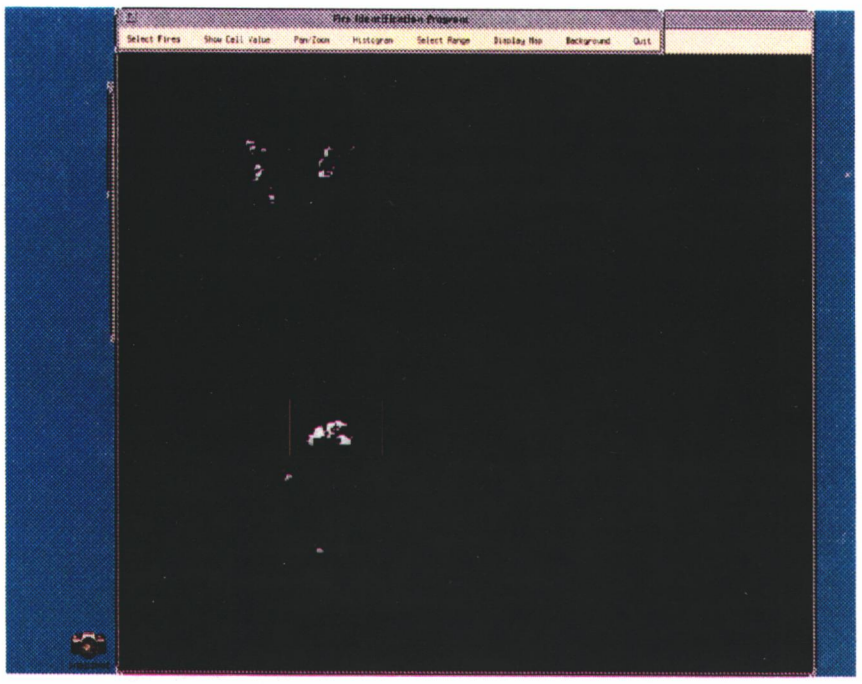
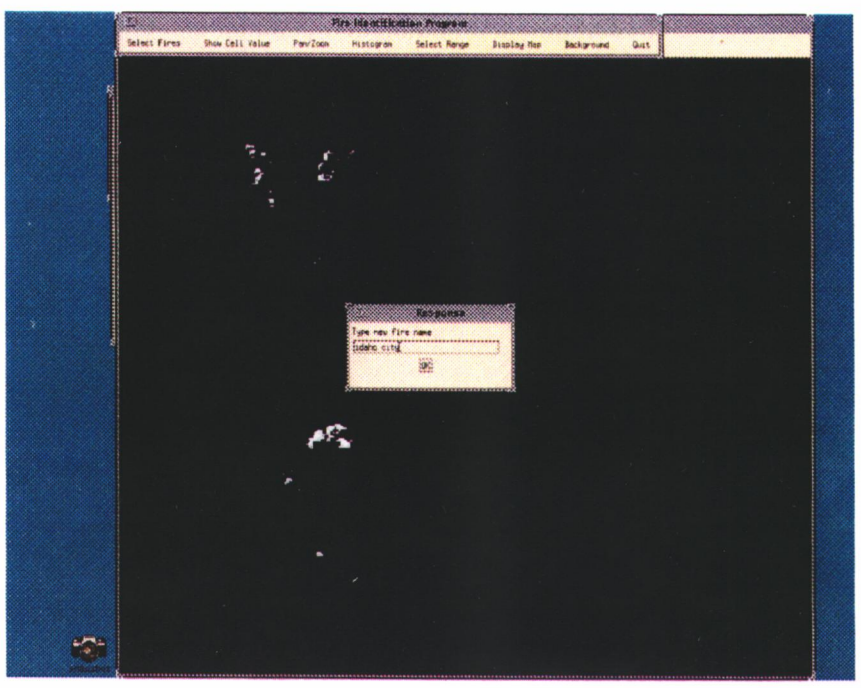


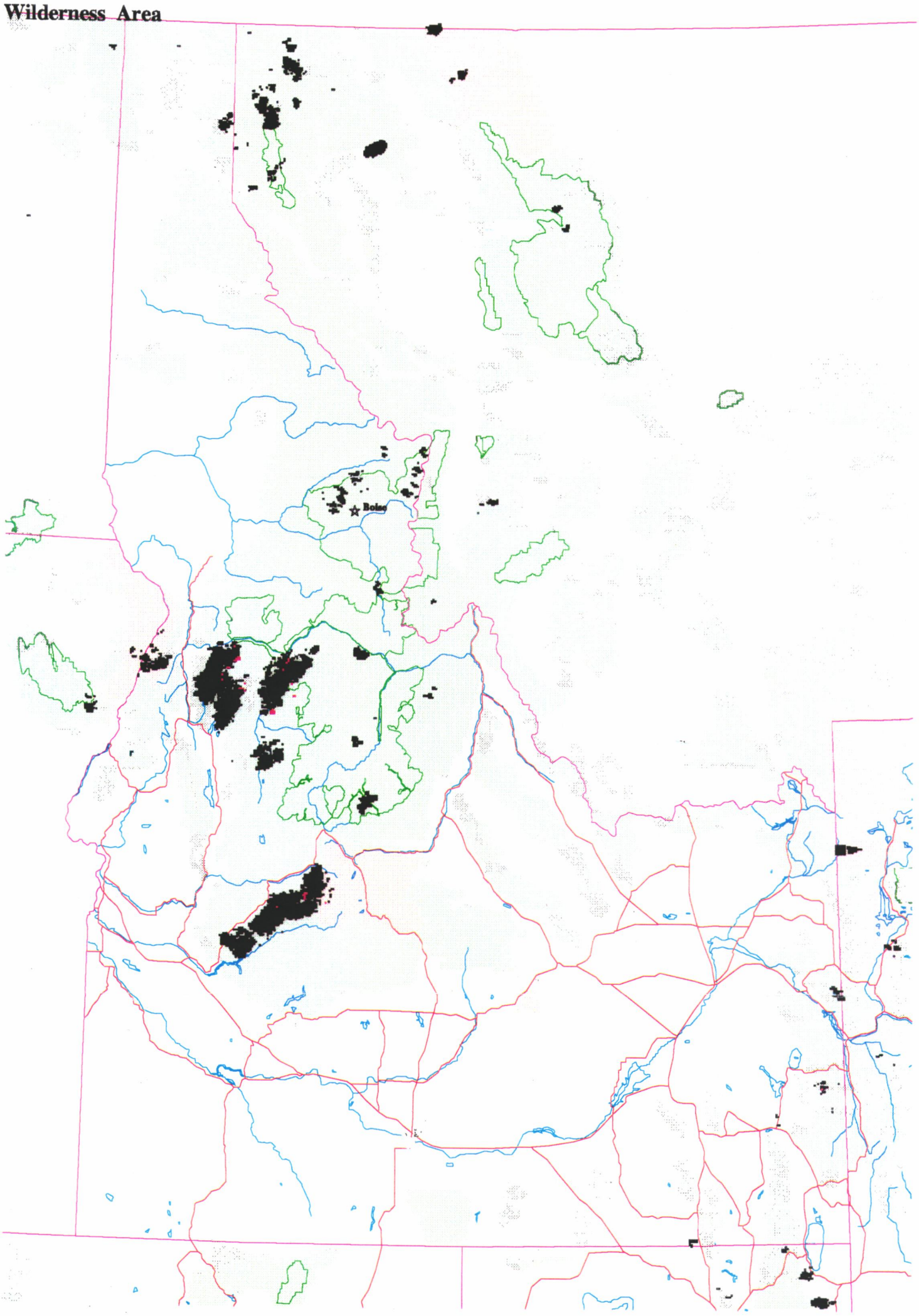



**US Department of Agriculture**
**FOREST SERVICE**
**Region Four**

## Cumulative Fire Spread from Aug 5, 1994

**Date September 18, 1994**
**Time 2027 MDT**

- National Forest
- NRA or Natl Park
- Active Burning
- Previous Burn Area
- Lakes and Streams
- Main Roads
- State Boundary
- Wilderness Area




**Fires mapped using AVHRR Tyros Satellites (NOAA-11 & NOAA-12)**
**Data approximation varies from one to two kilometers.**

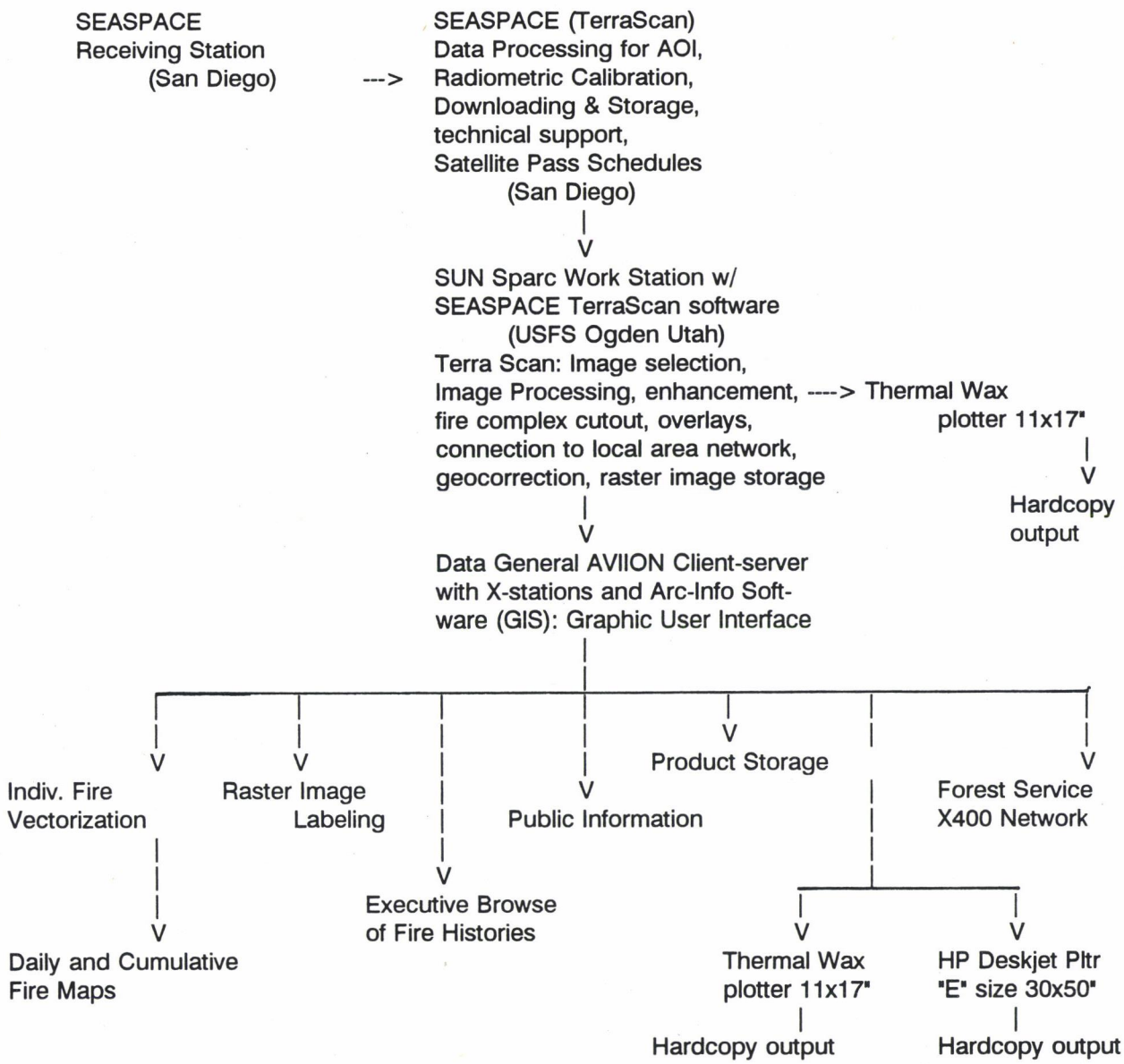
Figure 3 - Cumulative State Map of Fires from Vectorized Image.

C. Configuration

(1) Overview

SeaSpace Corporation provided a "turn key" application on a Sun Sparc workstation with their TerraScan software package. This application included the software to preview satellite schedule data at San Diego and to process raster data retrieved at Ogden Utah. Part of the product included a 9600 BAUD modem using data compression between San Diego and Ogden. Standard TCP/IP and TELNET protocol was used for all data migration between platforms. At the Ogden site, the Sun workstation was connected to the ethernet local area network, and applications were written in Arc-Info macro language (AML) for vectorization, cataloging, and displaying in the Geographic Information System (GIS).

(2) Diagram of Configuration



D. Processing

(1) Overview

At the Ogden Utah site, processing and workloads were organized into two primary objective areas once data was received. The goal was to (1) provide timely fire intelligence data, and (2) provide a cumulative fire history. In addition to attempting to get satellite views and enhancements on the Forest Service X400 network within one hour of a satellite pass, major daily products and enhancements were targeted of unit 7:00 am briefings.

Before images were retrieved, they were preselected for Nadir angle. Images with angles to target fire complex area generally greater than 30 degrees were omitted. Once retrieved, they were geocorrected and enhanced by various techniques including histogram stretches and color. Overlays for geographical reference were also added.. Specific windows or fire complexes by state were cut out. Fire names and other annotations were coordinated with National Intelligence Coordination Center (NICC) reports every morning. The best views in reference to time of day, cloud cover, or other interference were then processed to hard copy. Images illustrating peak burn periods (between 5pm and 10pm daily) were used for vectorized fire mapping. Vectorization was done on a GIS system and daily and cumulative fire progress products produced.

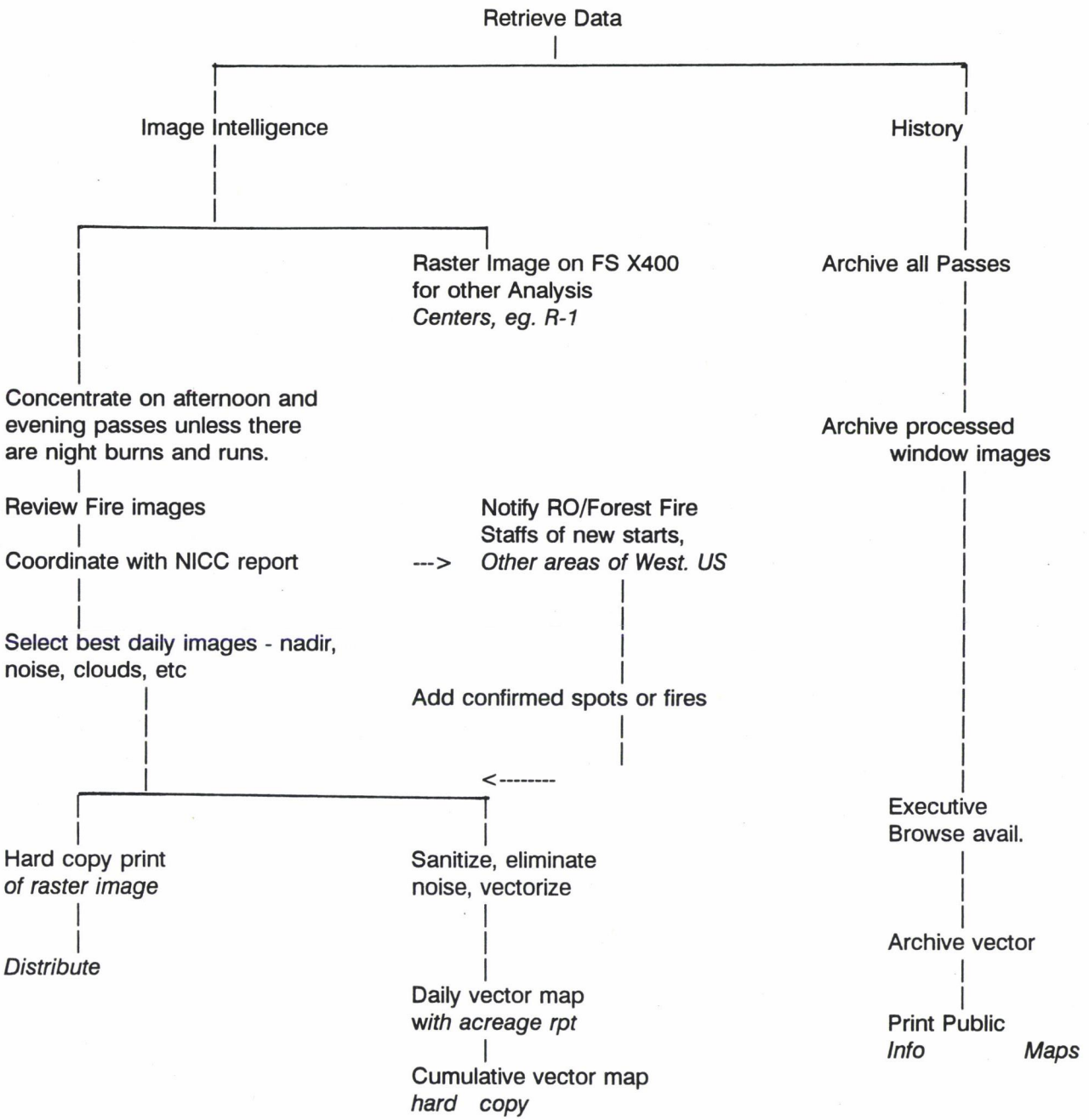
2. Satellite Timeframes and Platforms

For the most part, NOAA-11 and NOAA-12 were used in the study. On Day 43, NOAA-11 ceased operating, and NOAA-9 was used to finish the final two days of data collection. NOAA-13 was not used because its orbit placed it almost directly behind NOAA-12 during the study period. Each platform, based on polar orbits of the earth, made two passes each day of the Western US; however "true" nadir over exactly the same ground location was every five days. Each platform was at an altitude of approximately 430 miles. The passes between NOAA-11 and 12 were spaced approximately as follows:

| | |
|---|---|
| NOAA-12 | 6:30 am MDT |
| NOAA-11 | 9:00 am MDT |
| NOAA-12 | 5:30 pm MDT |
| NOAA-11 | 8:00 pm MDT |

3. Organization and Data Flow

Workforce management was divided among several primary tasks: (a) properly archive data, (b) make the data available to other analysis sites and process, and (c) process the data for electronic and hardcopy distribution. Coordination with the NICC (National Intelligence Coordination Center) morning reports was imperative in proper fire identification, naming, and tracking.



## E. Future Developments and Applications

Future development would logically include expansion of the technology toward fire detection through the development of equations to separate background reflections from fire heat sources. Some preliminary work has been accomplished on this subject. The addition of 24 bit monitors versus 8 bit monitors also would significantly enhance spot fire visualization.

Additional fire applications could include smoke monitoring, wilderness prescribed natural fire monitoring (refer to Image 3), mapping fire fuels or fuel loading ahead of fires, fuel moisture readings (greenness), and terrain analysis incorporated with fire behavior analysis. Vector files could easily be superimposed over shaded-relief topography maps, display in 3-D, and rotated in animation.

Other applications include vegetation monitoring, snow cover monitoring, hydrology, day/night temperature differentiation, and ARGOS animal tracking. Use could also be made of the AVHRR platforms for National emergency monitoring including floods, hurricanes, weather, and volcanic activity.

New satellite platforms to be launched in the immediate future would include the ability to map ambiant humidity, and not to be overlooked is the acquisition of data from military satellite platforms.

## F. Costs

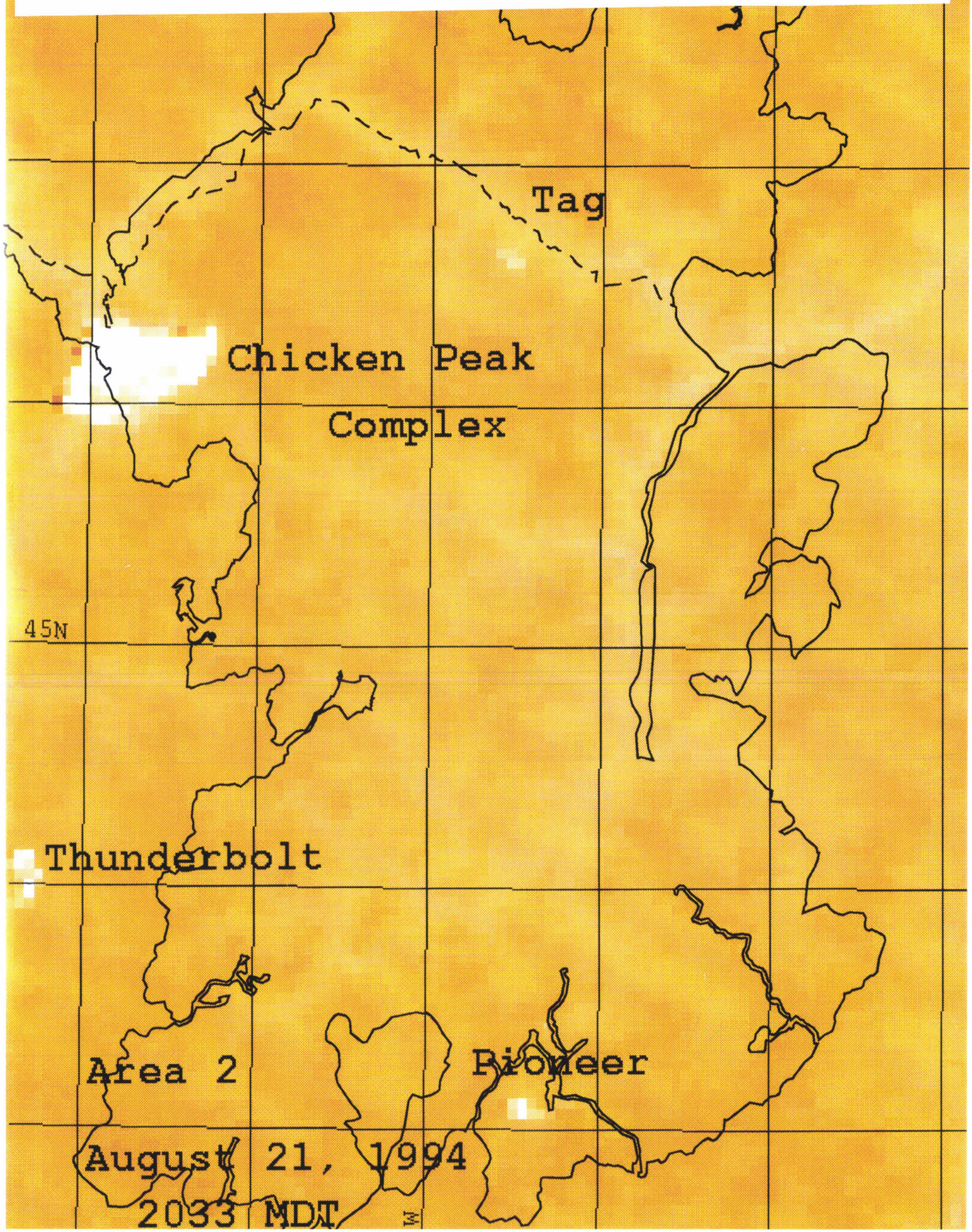
Costs associated with this project included $25,000 for the SunSparc Workstation with modem, 2 GB storage, 32 MB memory, 15 inch monitor and key board, pre-loaded with TerraScan software. Satellite data costs were $150.00 per opportunity to download satellite passes. With approximately four passes daily from NOAA 11 and 12, this amounted to $4200 per week. SeaSpace Corporation also sells a portable receiving station which would reduce data acquisition costs for large scale monitoring and downloading. One receiving station could cover the entire western United States and Alaska.

Other costs saving could be explored with using other US Government operated receiving stations from NOAA and the US Weather Service. Timeliness of data receipt and transfer are the question here.

The GIS system including workstation and Arc-Info software were in place as were local area networks (LAN).

Operational costs for personnel are reasonable. Training to operate the TerraScan and GIS systems, both with Graphic User Interfaces, is less than a day. Three people on a 12 hour shift were able to handle downloading and processing of all satellite passes over a two Region area. Four to five trained and experienced people could easily handle the strategic monitoring of all fires in the Western United States with the two systems. It is also recommended that one additional person skilled in RISC technology and systems be assigned to keep systems operational, perform backups, and configure peripherals.

Image 3 - Wilderness Wildfire Monitoring for the Frank Church-River of No Return Wilderness Area.



APPENDIX

A. Processing Considerations

(1) Sanitization

When making satellite data available for display, some scenes may be unacceptable for general distribution because of noise, interference, poor quality, clouds, etc. Therefore a screening process should be initiated wherein analysts receive and process the data, but general distribution to others is limited. Examples of external factors causing consideration for screening or sanitization are included in (2) thru (5) following:

(2) Nadir

Nadir refers to perpendicular position of the satellite to ground points of interest. The AVHRR system has a 55 degree angle of view from the satellite to the earth horizons (refer to Figure 3). However, an area of interest in the oblique view between 30 and 55 degrees would be highly distorted in the geo-correction process. This is because the interpreting software must interspace pixels into the area of interest image to meet earth coordinate points (rubber-sheeting). Fire data can still be carefully interpreted from such scenes, however distribution of the raw image may cause confusion to the reviewer (refer to Image 4 for an example of such distortion). As a general rule, selected images should be under 30 degrees satellite view angle to the earth location.

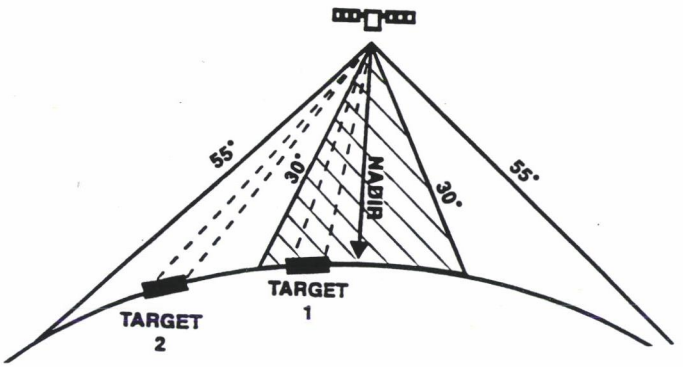



Figure 3 - Nadir Display

(3) Time of Day

The time of day or satellite overpass is important for several factors: (a) In fire detection and monitoring, fire activity (and thus visibility) is highly influenced by daytime heating and nighttime cooling with humidity gain and loss, and (b) Peak burn periods (around 3-5 pm) are also the times of greatest solar heating of the earth surface. This high solar heating tends to make bare areas, rocks, lakes, etc., warmer than surrounding areas and thus more visible on thermal sensors. Refer to Image 5 for an example of surface heating. Based on general experience it is preferable to analyze images collected in the 9-10 pm timeframe before nighttime humidity recovery suppress fire activity and after areas receiving direct solar heating have cooled down.

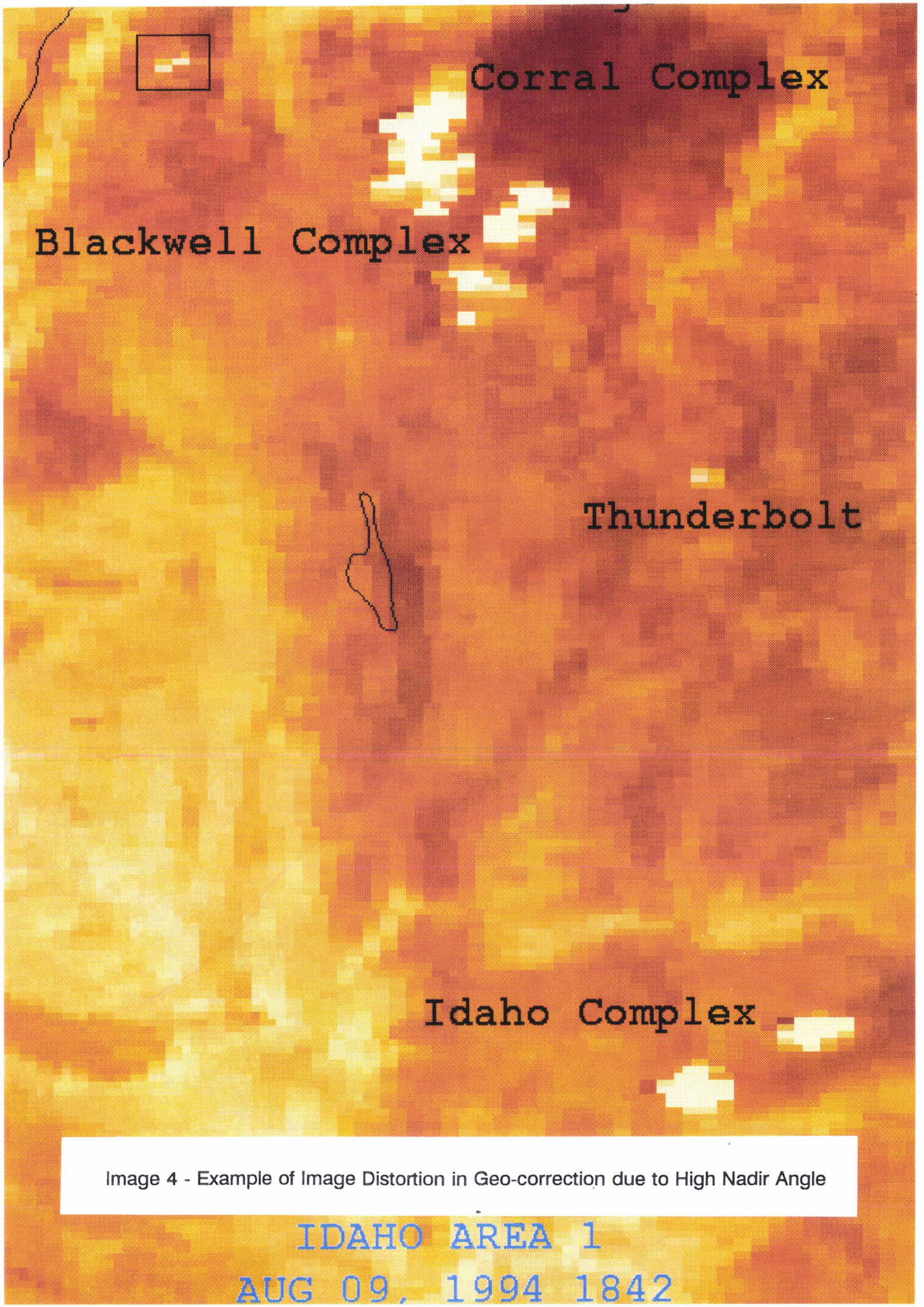



Image 4 - Example of Image Distortion in Geo-correction due to High Nadir Angle

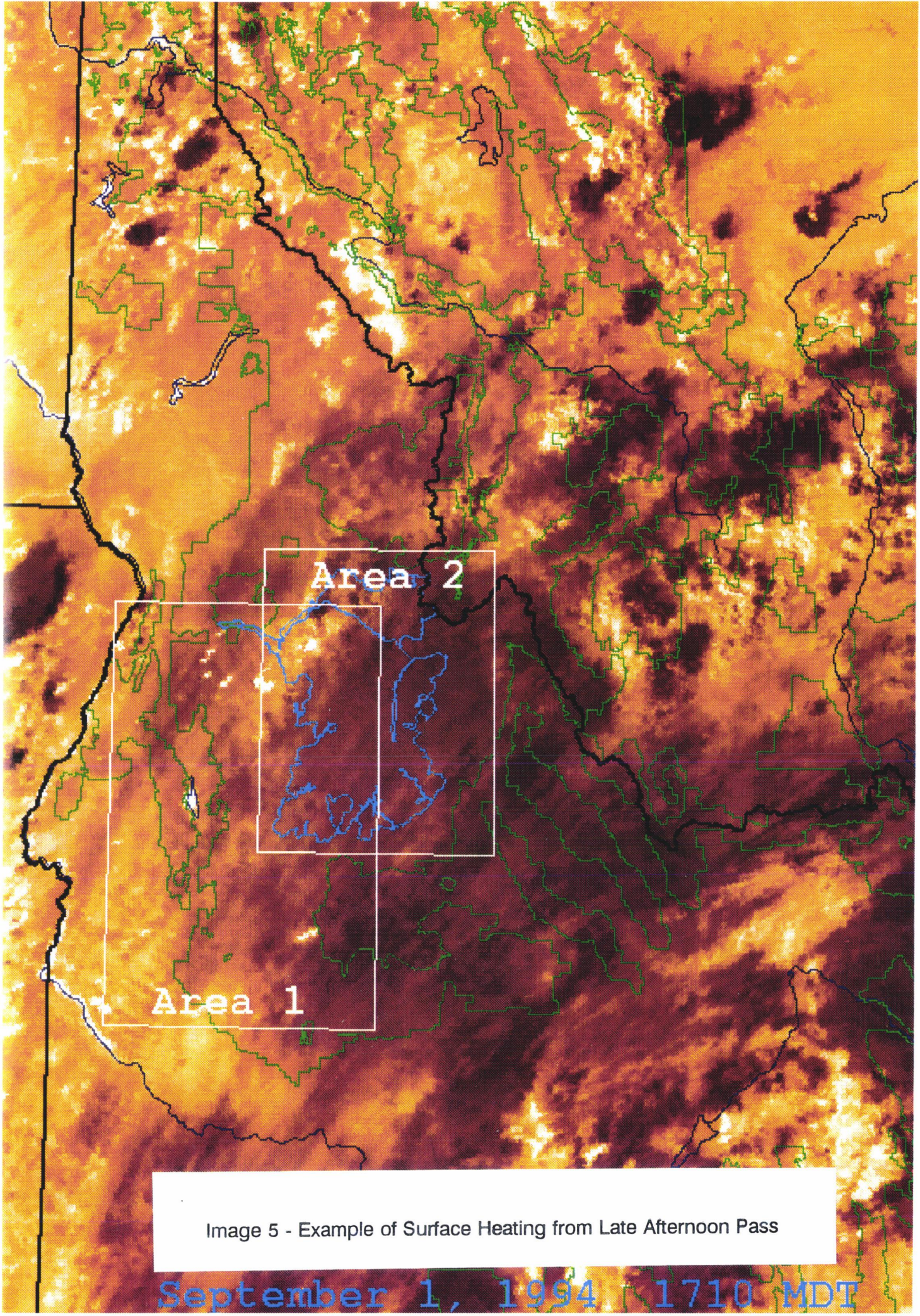



Image 5 - Example of Surface Heating from Late Afternoon Pass

(4) Clouds/Smoke

Clouds, particularly those containing moisture and ice, restrict the monitoring of fires. Smoke is not a major factor in fire monitoring and appears transparent when using Band 3 of the AVHRR series. Many of the images included in this document contain clouds which appear as the darker areas (cooler) whereas hot thermal areas, such as fires appear bright.

(5) Interference

Two principle types of interference or data confusion were noted during the project. These were Lightning and Sun Reflection.

Lightning was noted and correlated to other lightning monitoring platforms on several occasions (refer to Image 6). Because it was impossible to separate or distinguish lightning strikes from new fire starts of a pixel or less in size, prediction of new fire occurences required conformation on two or more individual satellite passes.

Sun reflection that highly confused image interpretations was noted as occurring about once a week on single images. This reflection appeared much the same as solar warming of specific ground features such as rock, bare soil, etc. except that water bodies, including small lakes and ponds, were most dramatically effected. Because the reflection was confused with high thermal readings, some images were difficult to use. Reflection problems occurred with both late in the afternoon and early morning satellite passes when for instance; (a) the satellite nadir was West of the target area and the sun was coming up in the East, or (b) the satellite nadir was East of the target area and the sun was setting in the West.

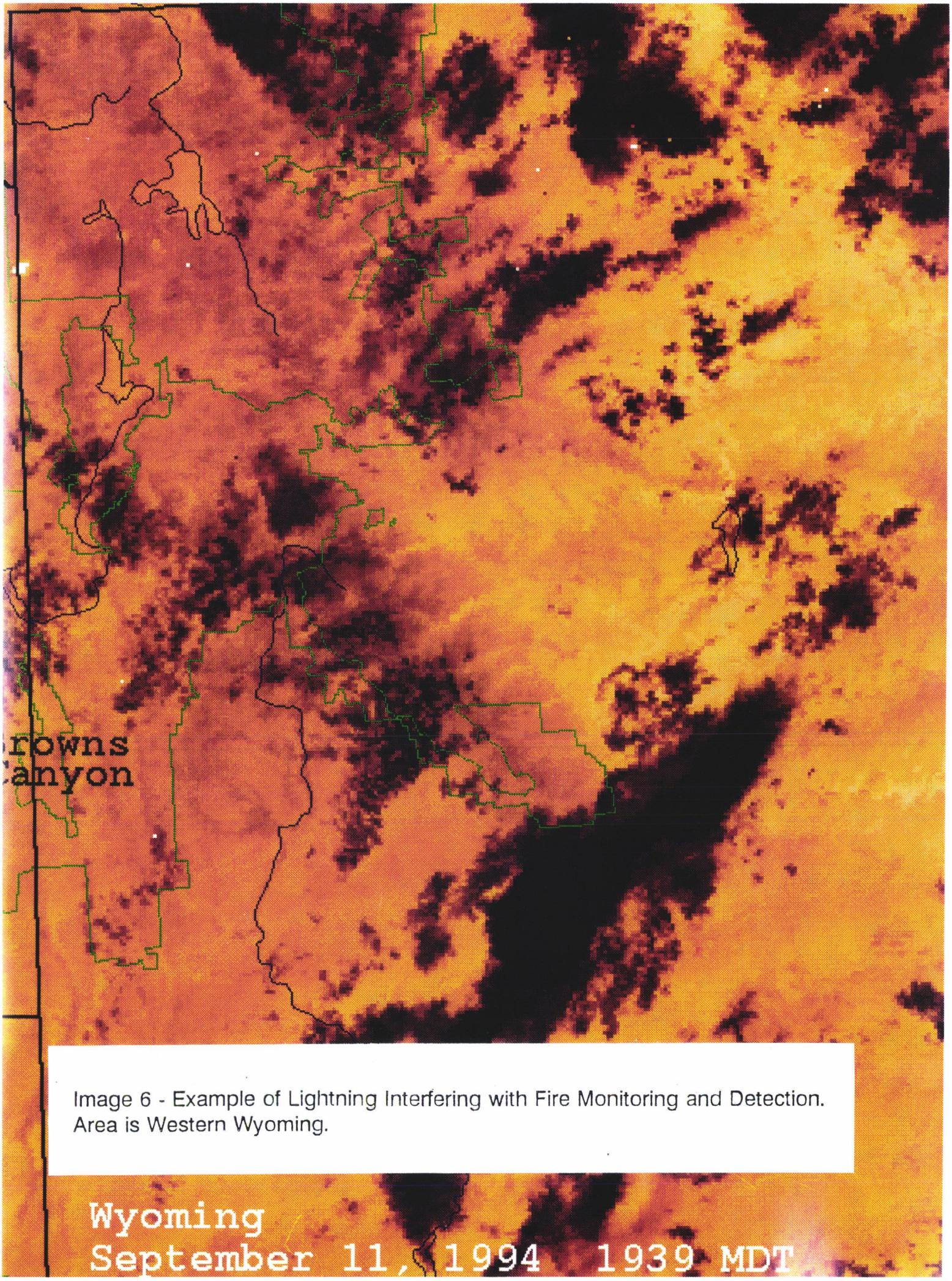


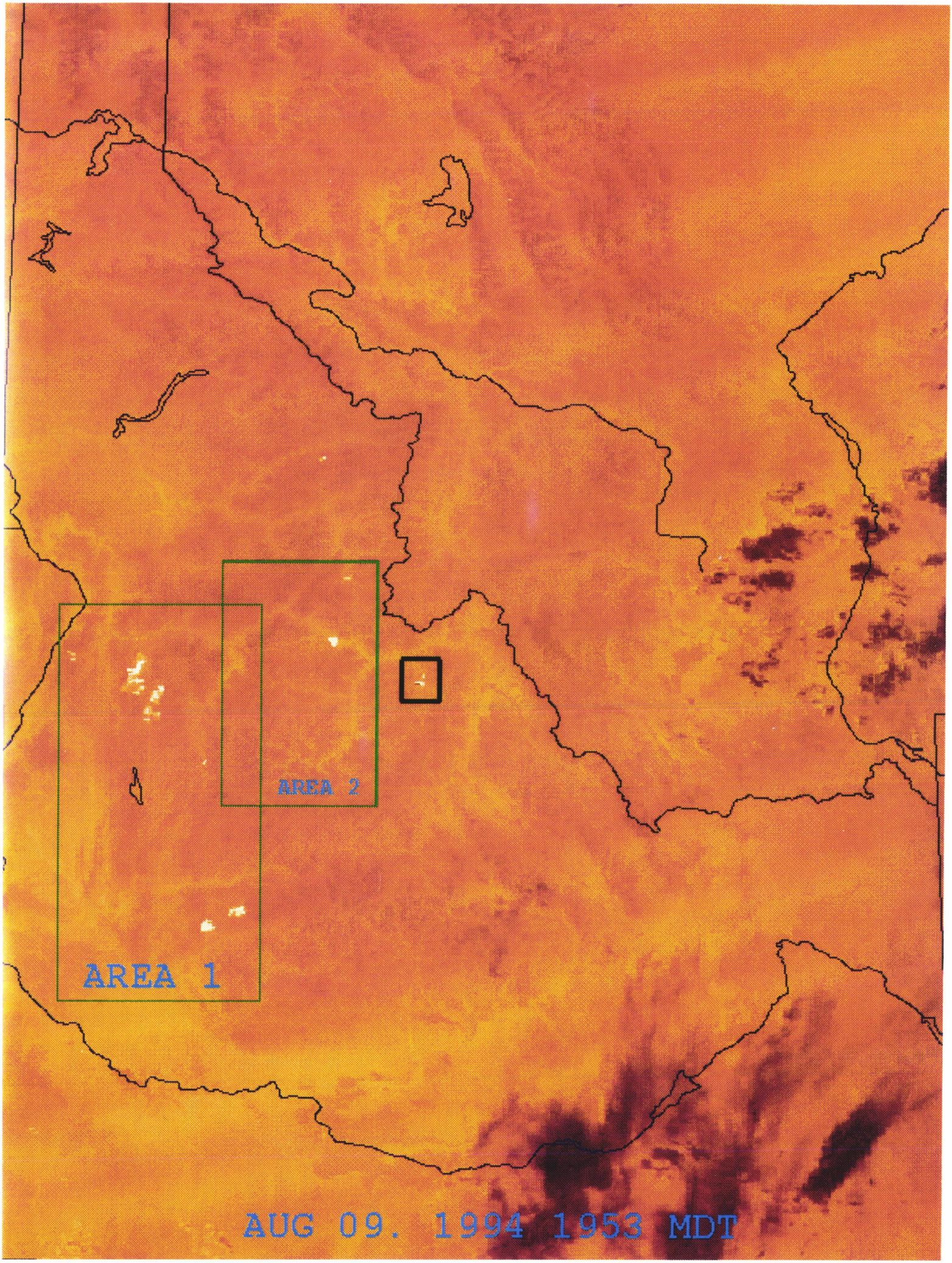

Image 6 - Example of Lightning Interfering with Fire Monitoring and Detection. Area is Western Wyoming.

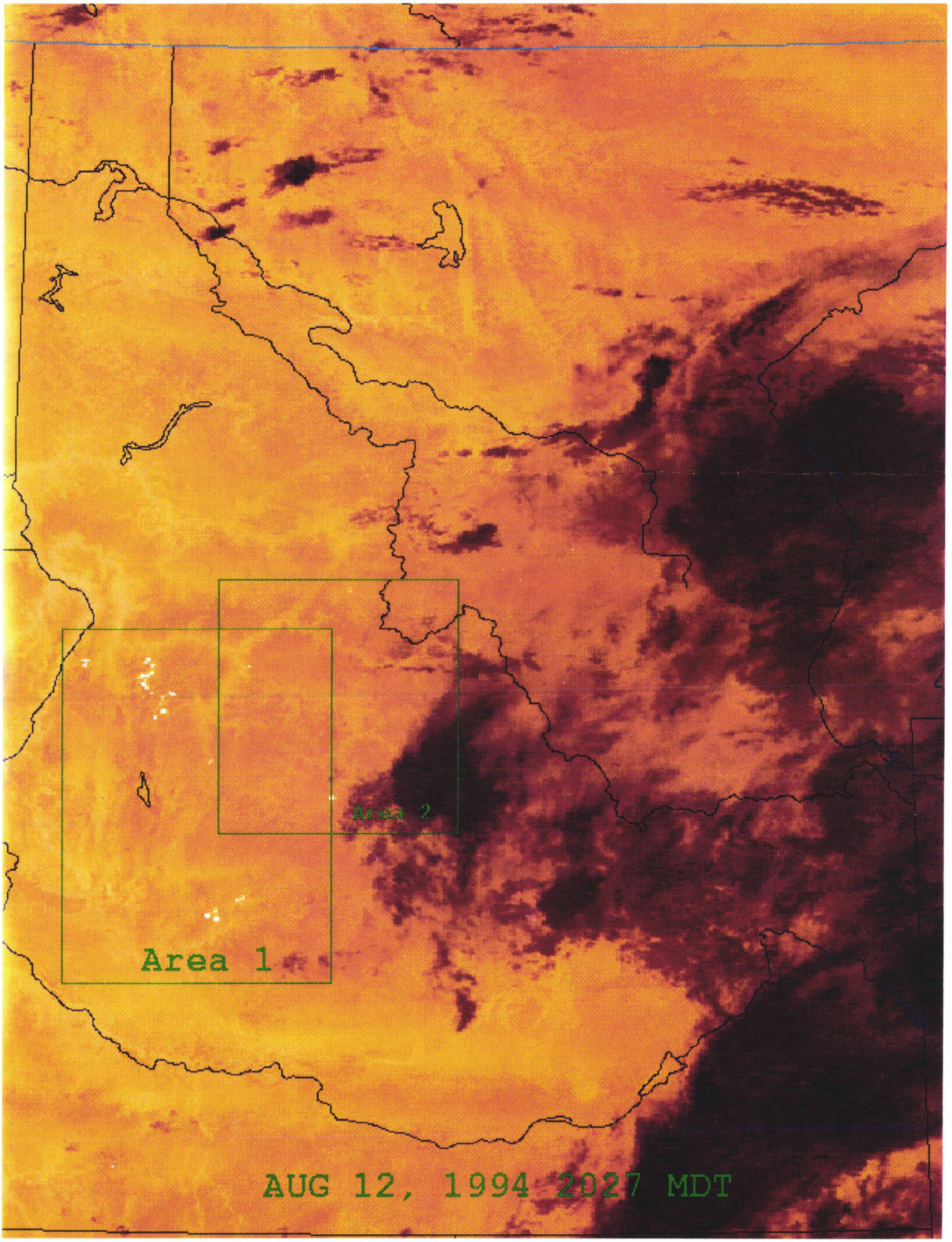
B. Product Examples

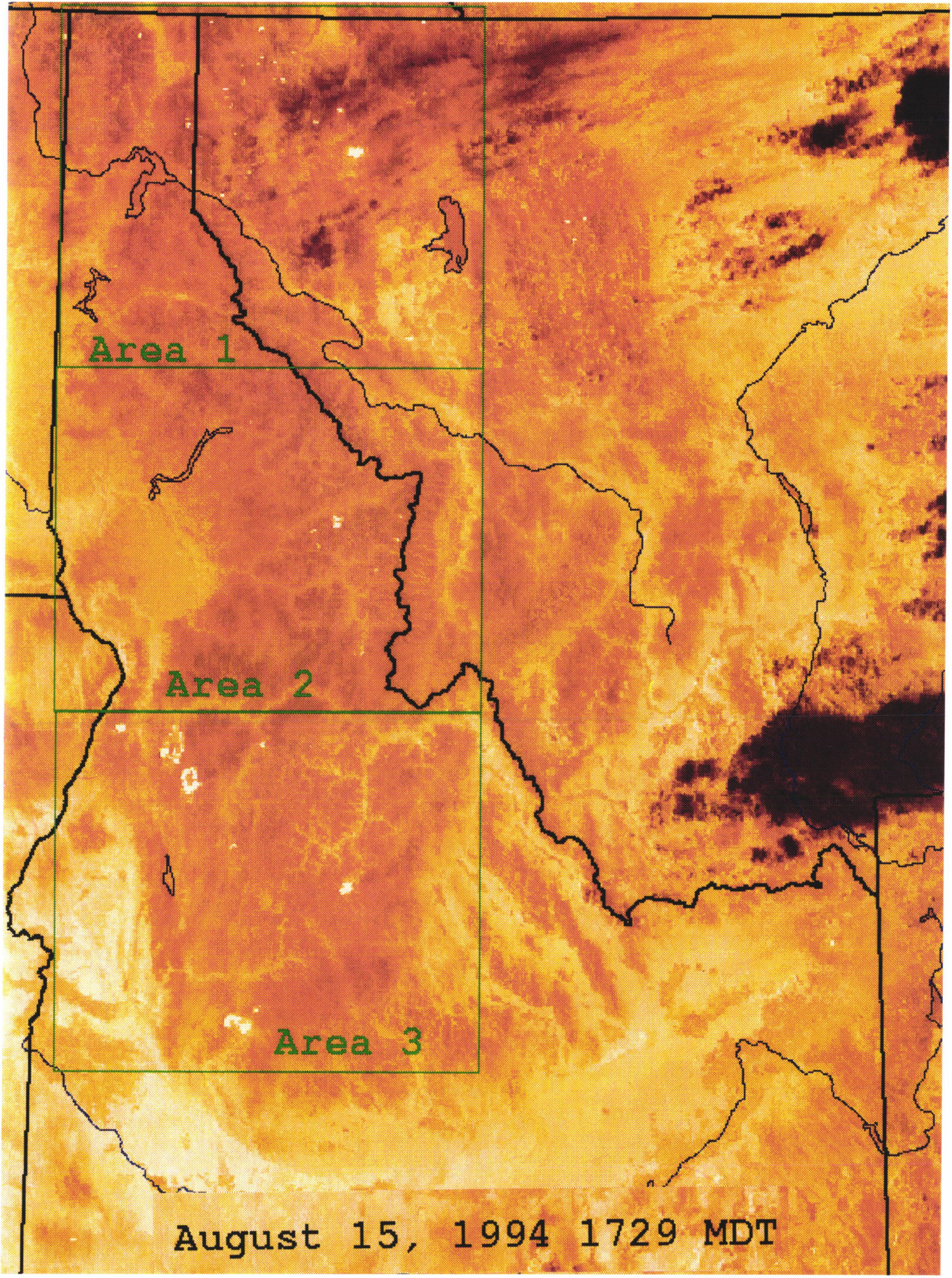
(1) Raster

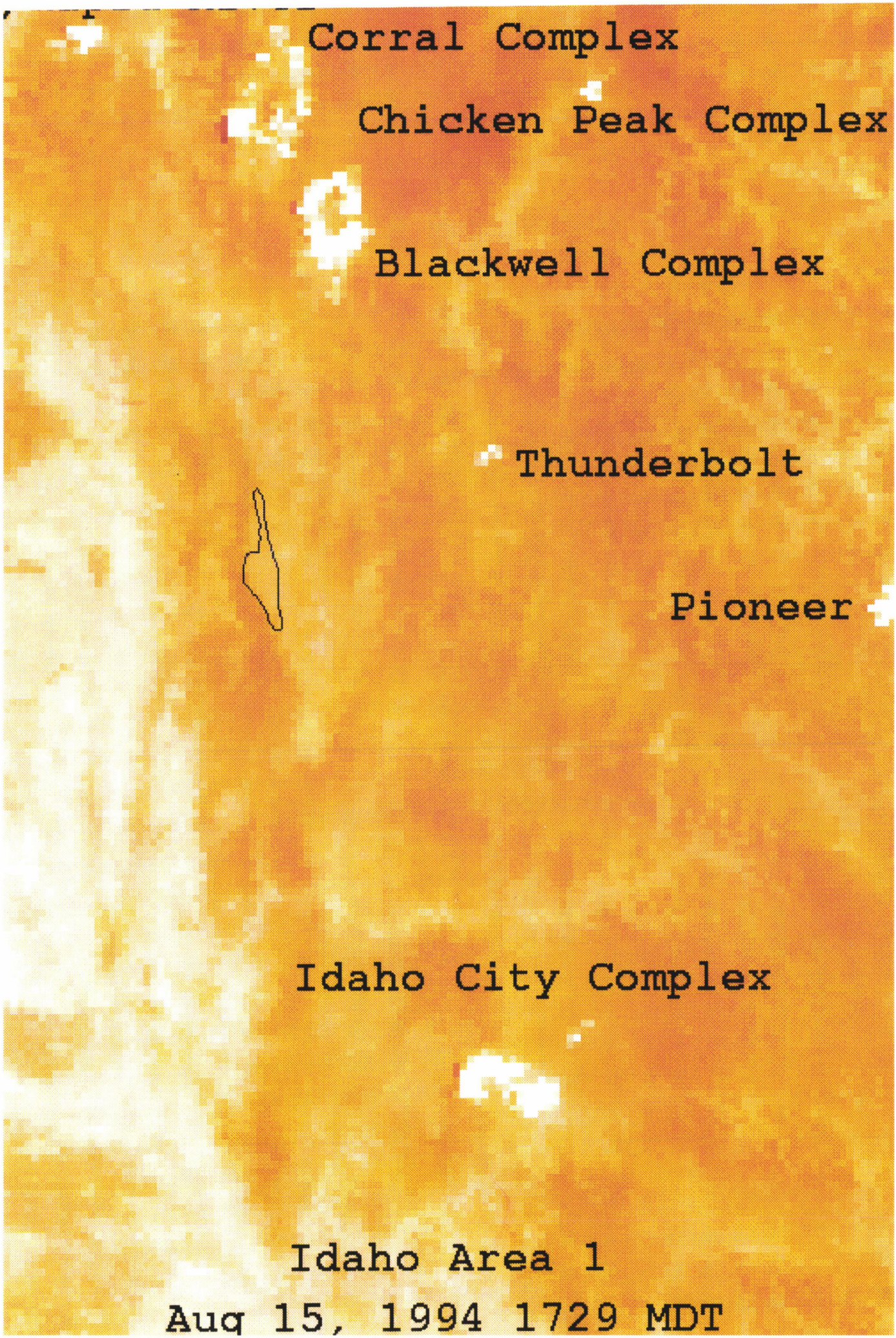
Raster products were produced with the TerraScan system. Only band 3 is displayed with a contrast stretch to enhance the visibility of heat sources or fires. For ease of viewing in the concept of time, the following examples concentrate on the Idaho Fire Complexes for the duration of the monitoring program with scenes displayed progressively every four to five days.

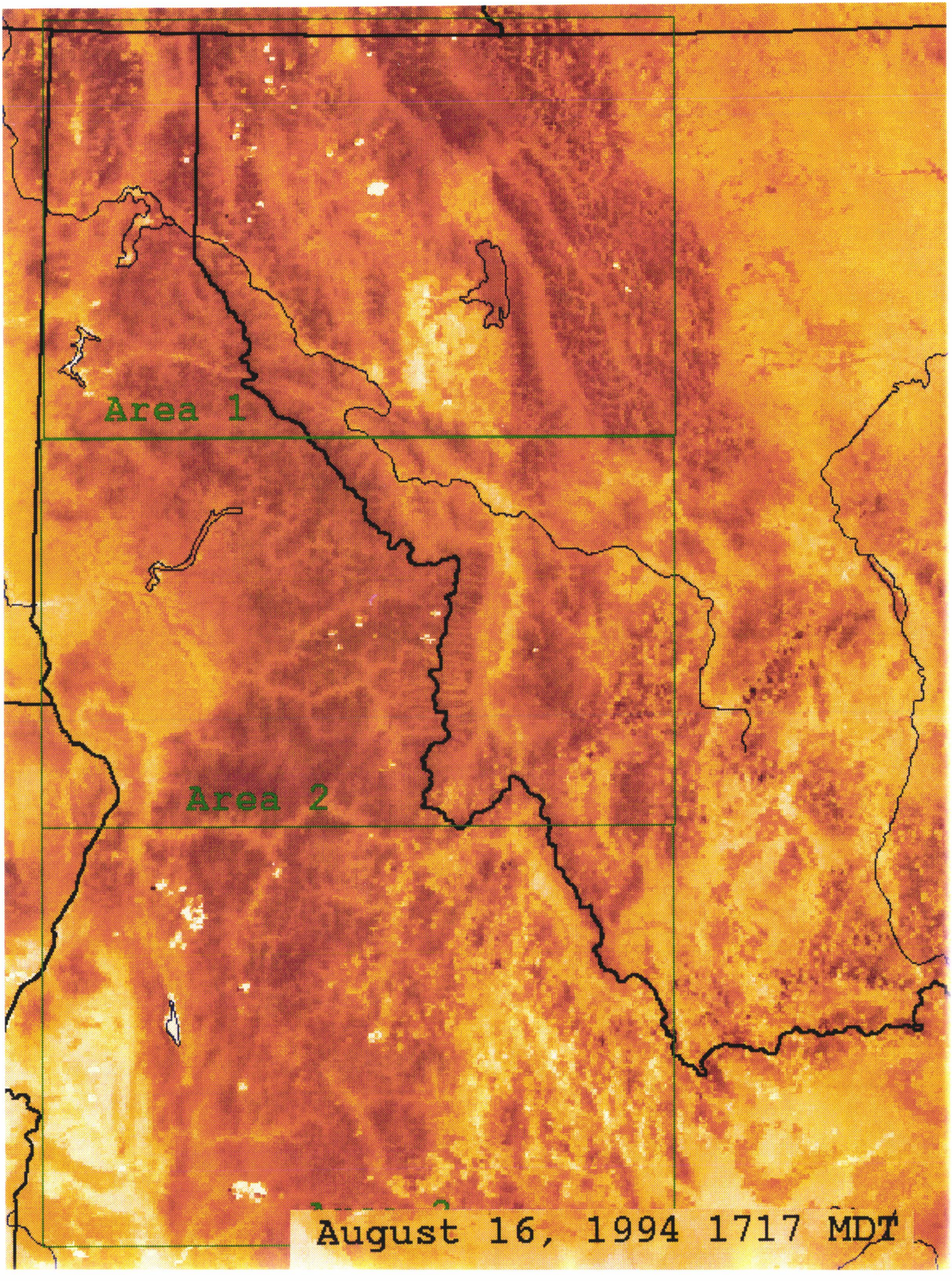
Fires or high temperature pixels can be seen in white, while clouds are the dark reds and blacks. Note that smoke is basically transparent with this band frequency. Landforms can be distinguished in the orange colors. These raster images were processed with the SEASPACE TerraScan system.

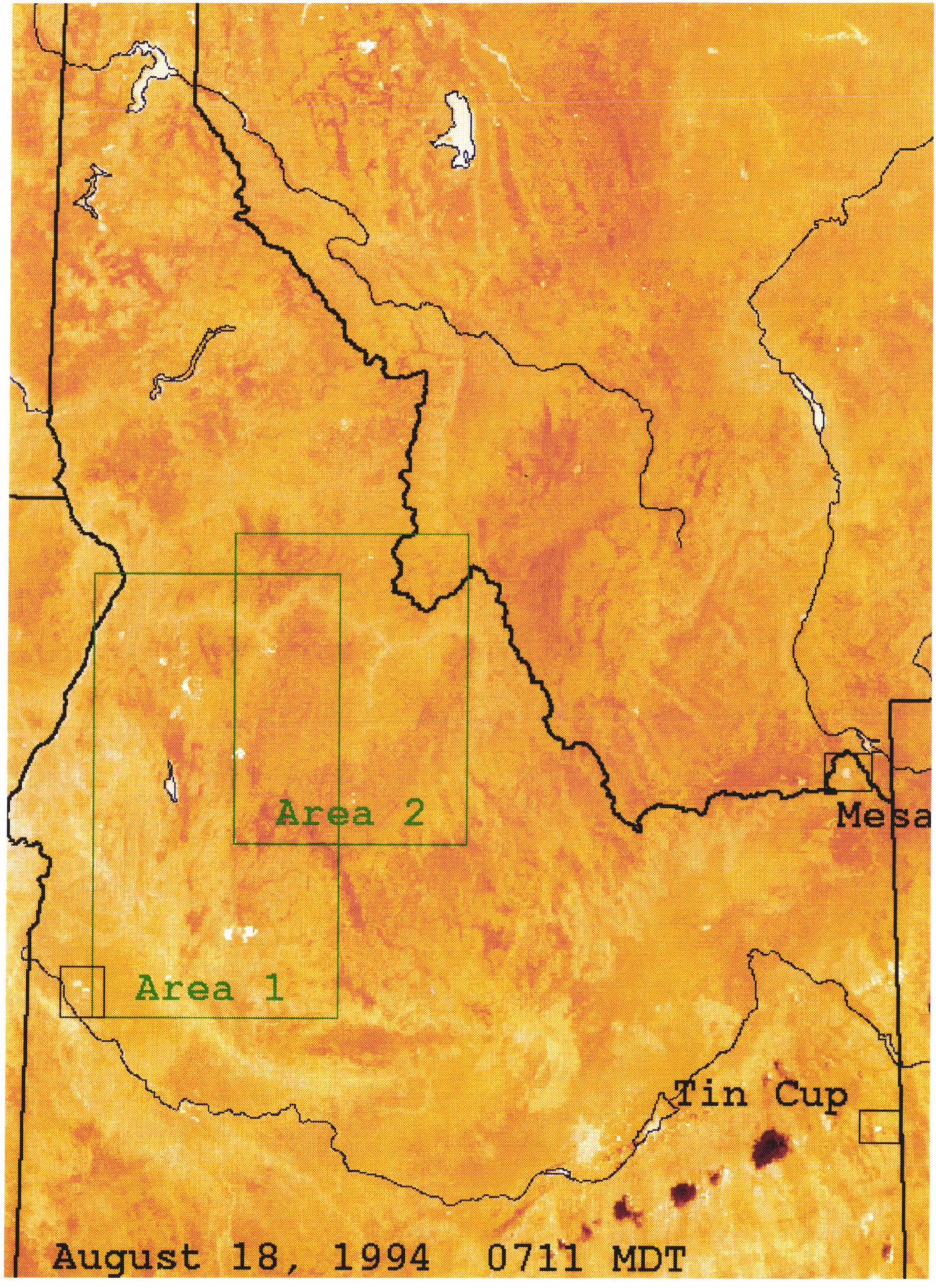

AREA 2
AREA 1
AUG 09. 1994 1953 MDT

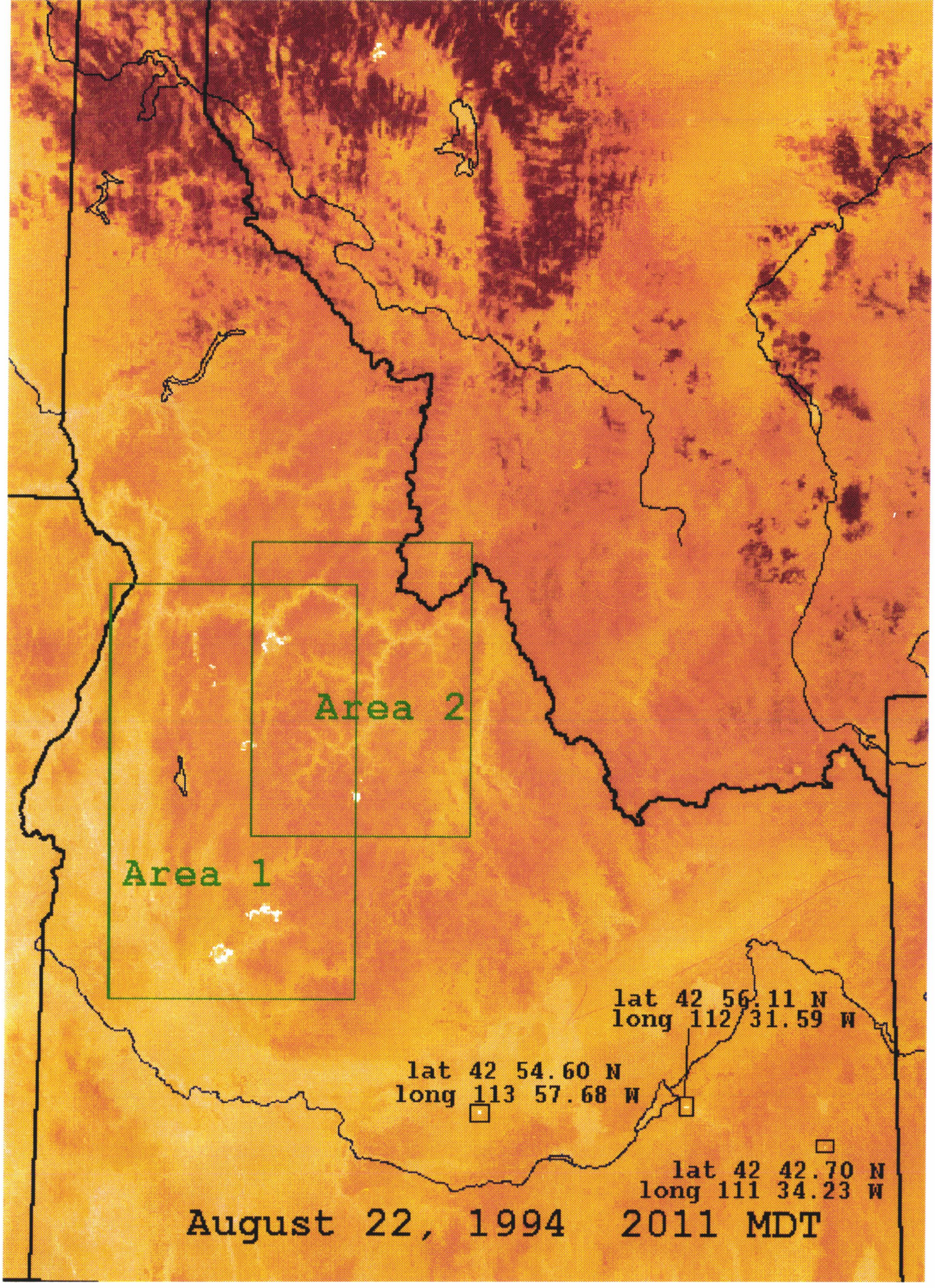

Area 2
Area 1
AUG 12, 1994 2027 MDT

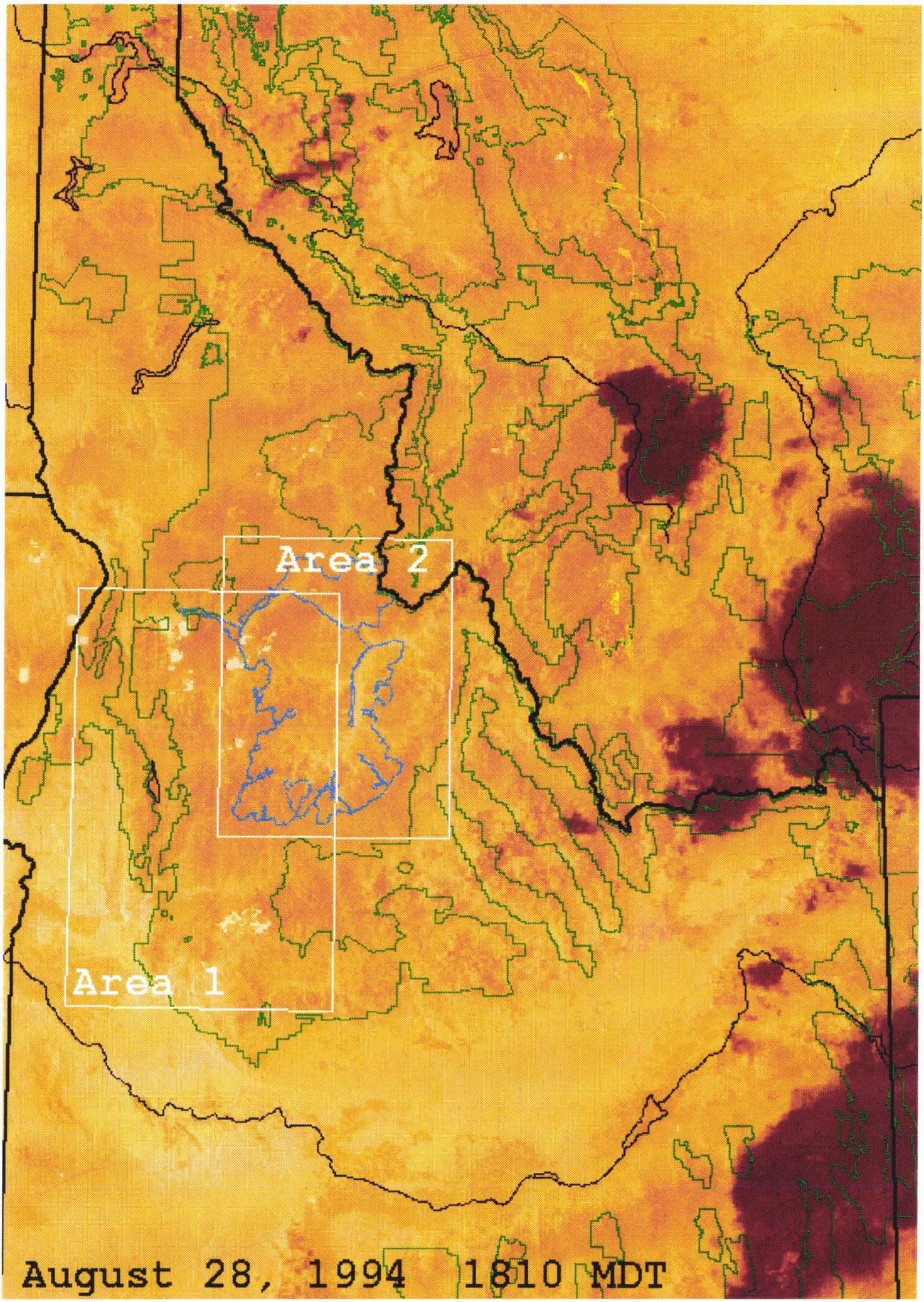

Area 1
Area 2
Area 3
August 15, 1994 1729 MDT

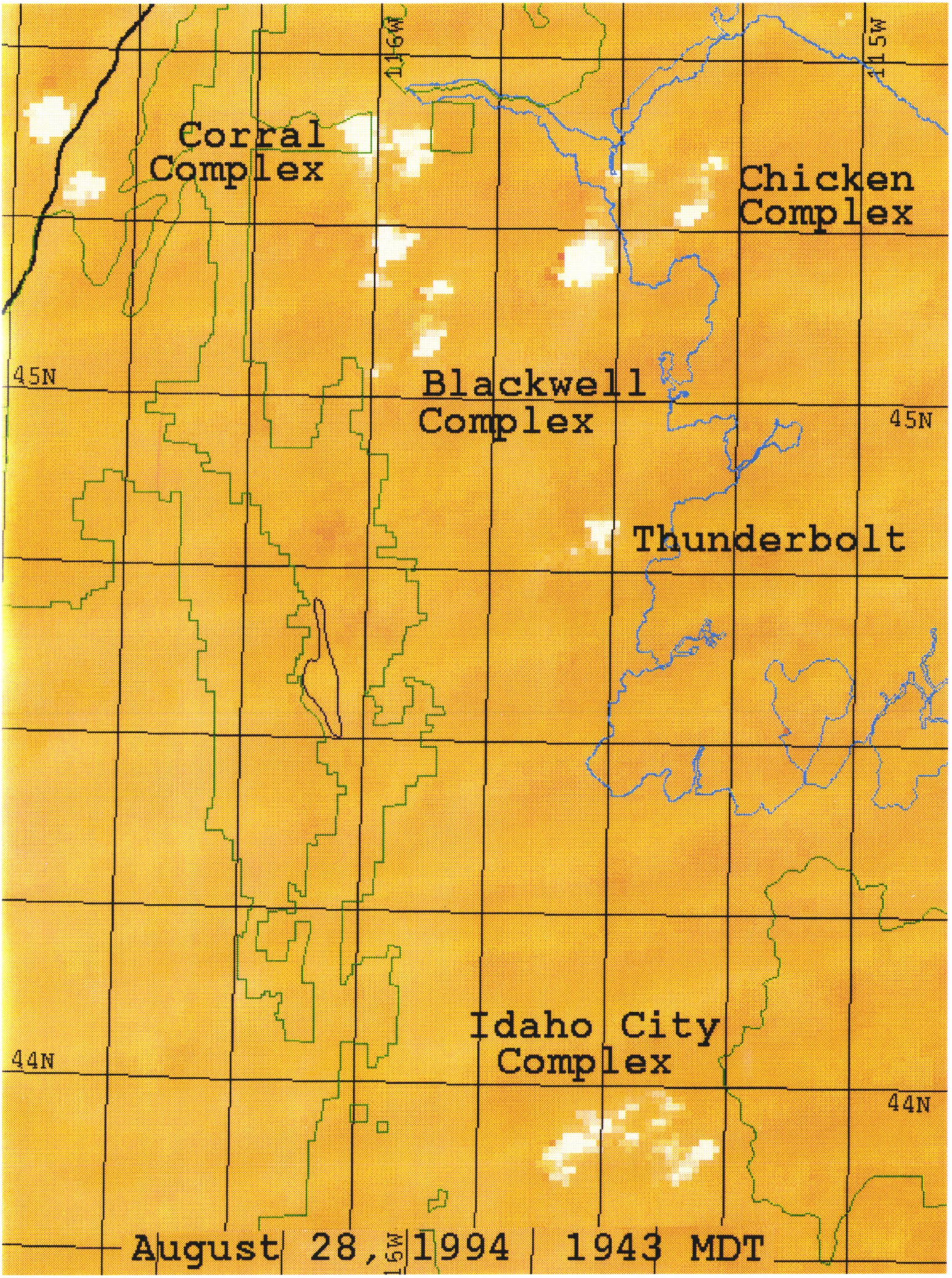

Corral Complex
Chicken Peak Complex
Blackwell Complex
Thunderbolt
Pioneer
Idaho City Complex
Idaho Area 1
Aug 15, 1994 1729 MDT

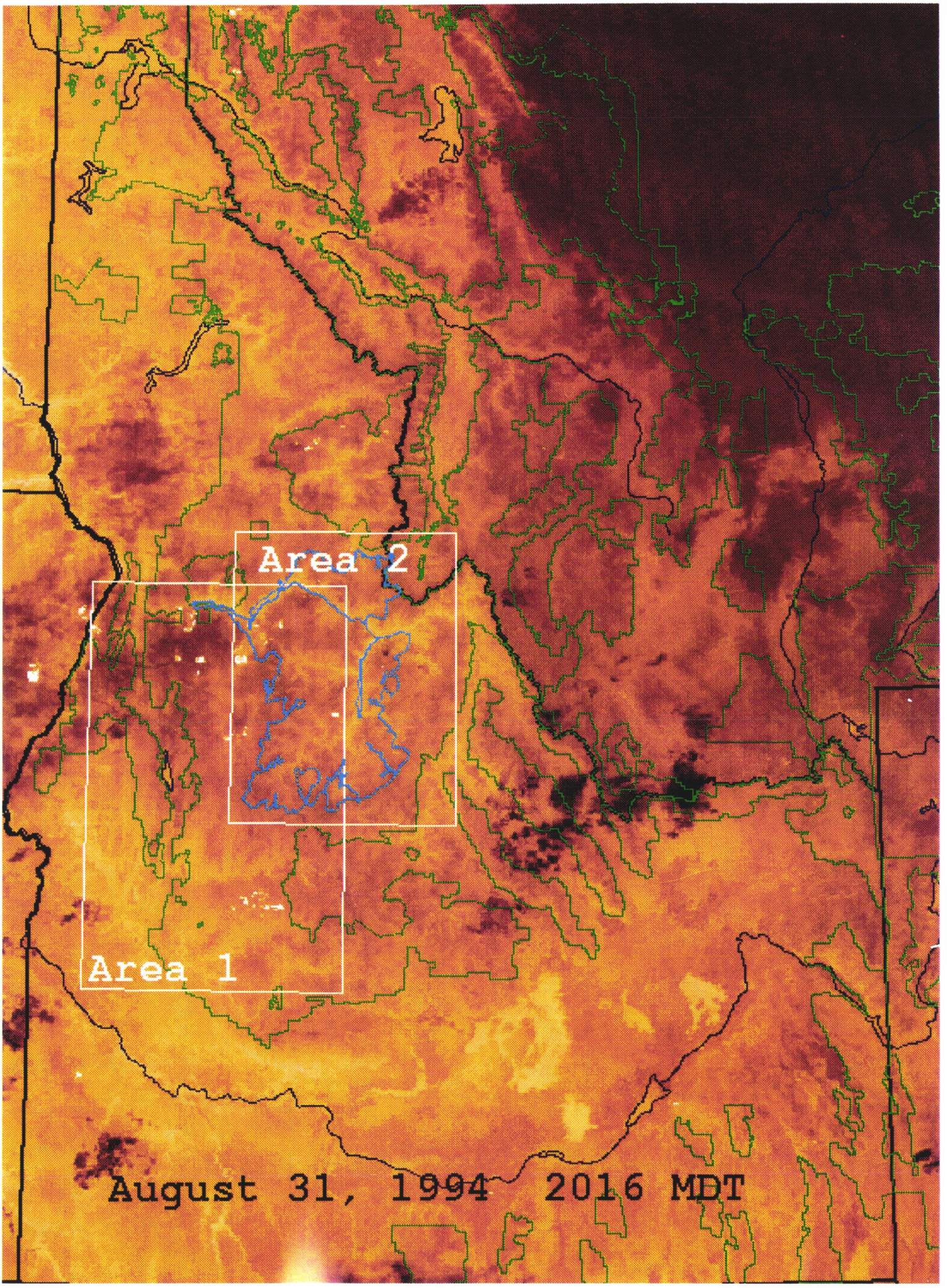

Area 1
Area 2
August 16, 1994 1717 MDT

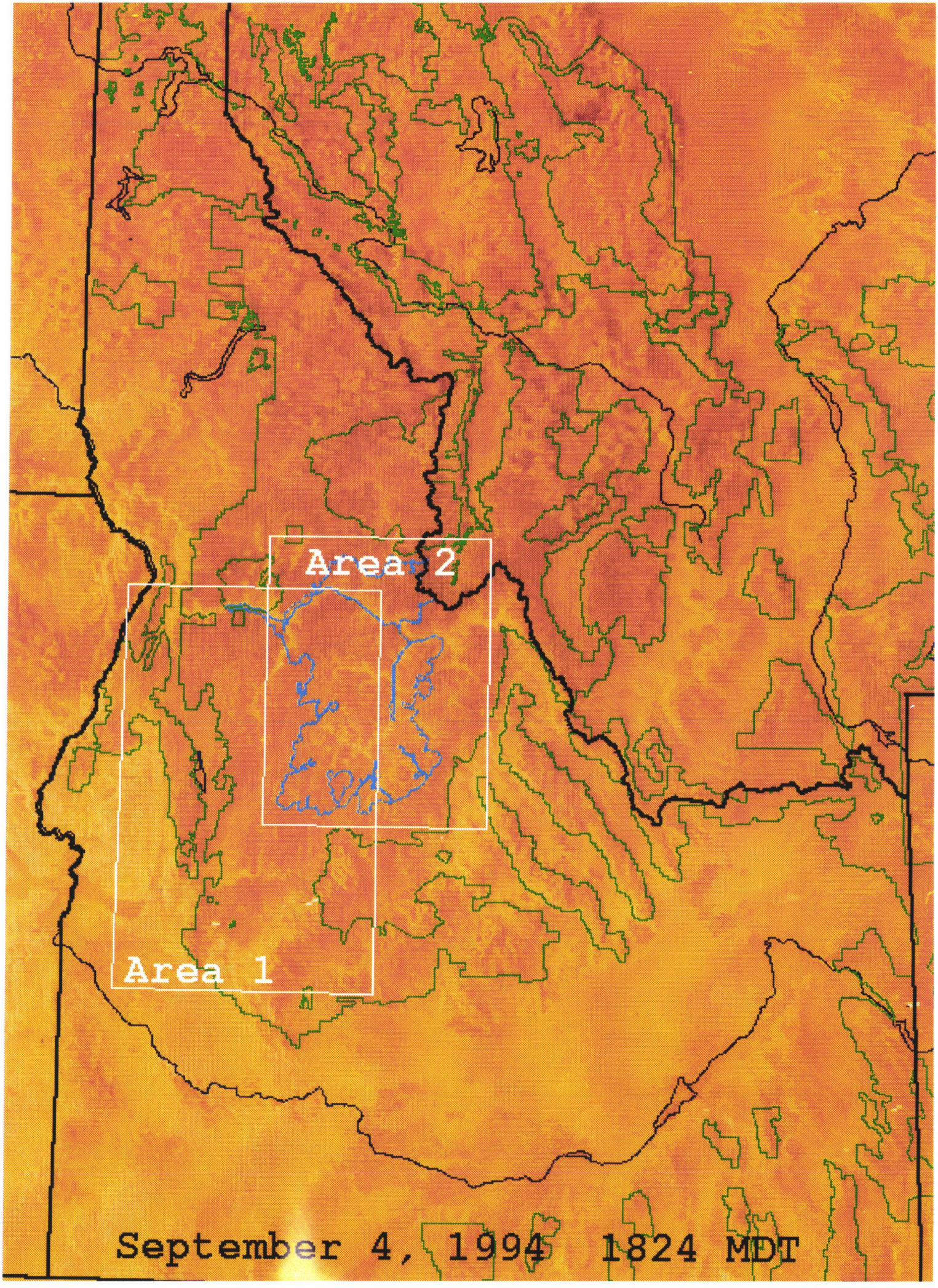

Area 2
Area 1
Mesa
Tin Cup
August 18, 1994 0711 MDT

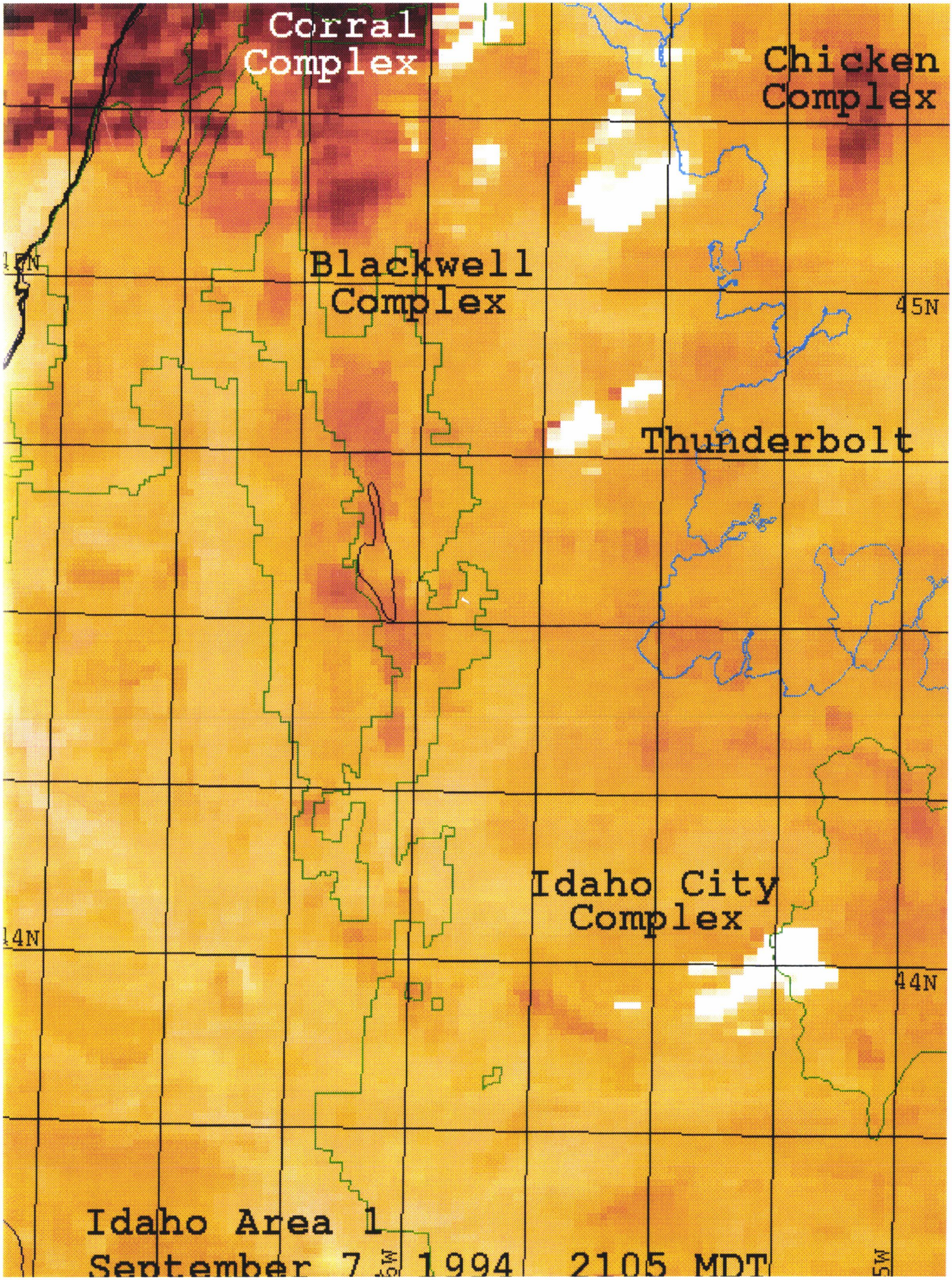

Area 2
Area 1
lat 42 56.11 N
long 112 31.59 W
lat 42 54.60 N
long 113 57.68 W
lat 42 42.70 N
long 111 34.23 W
August 22, 1994 2011 MDT

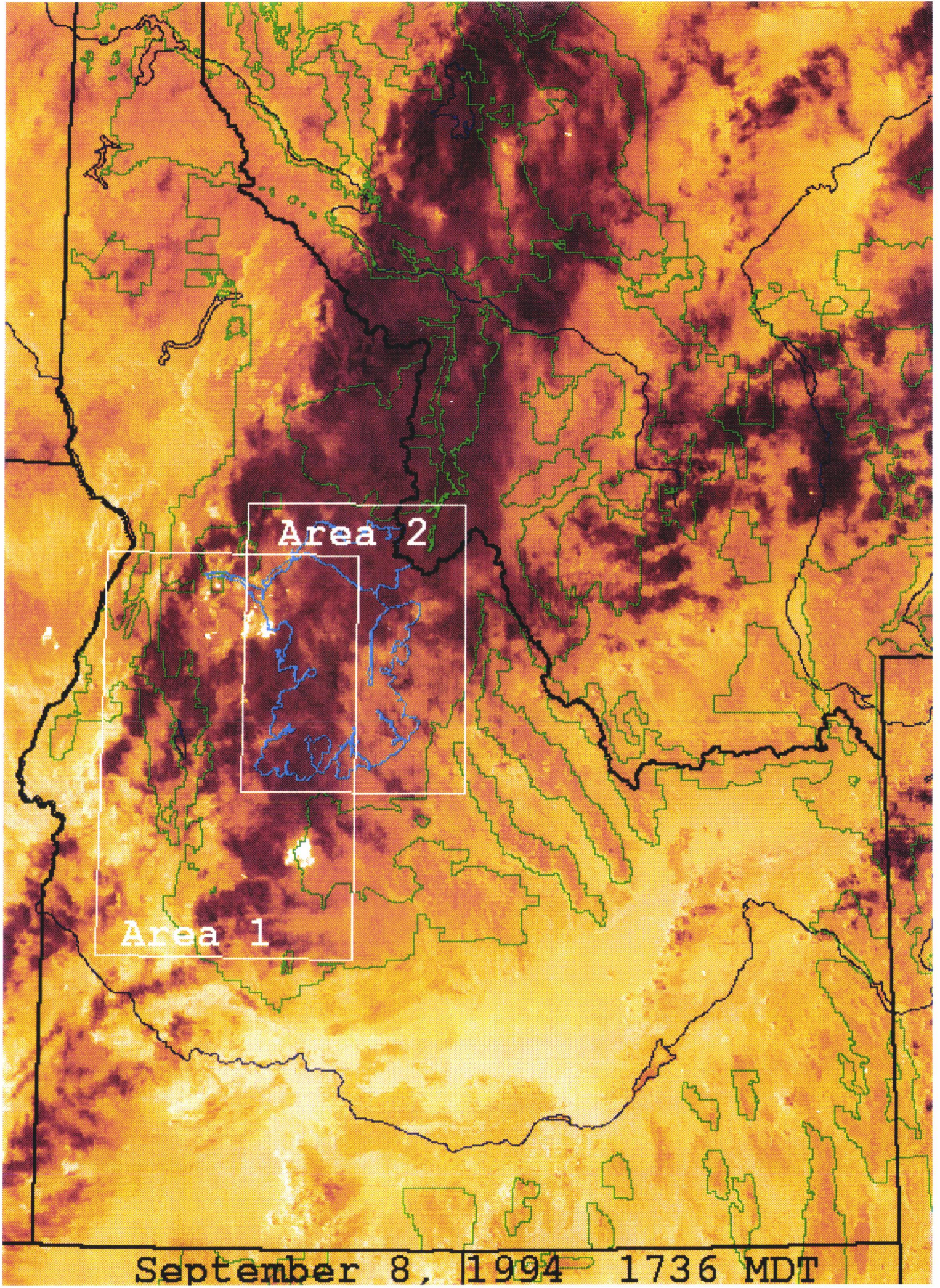

Area 2
Area 1
August 28, 1994 1810 MDT

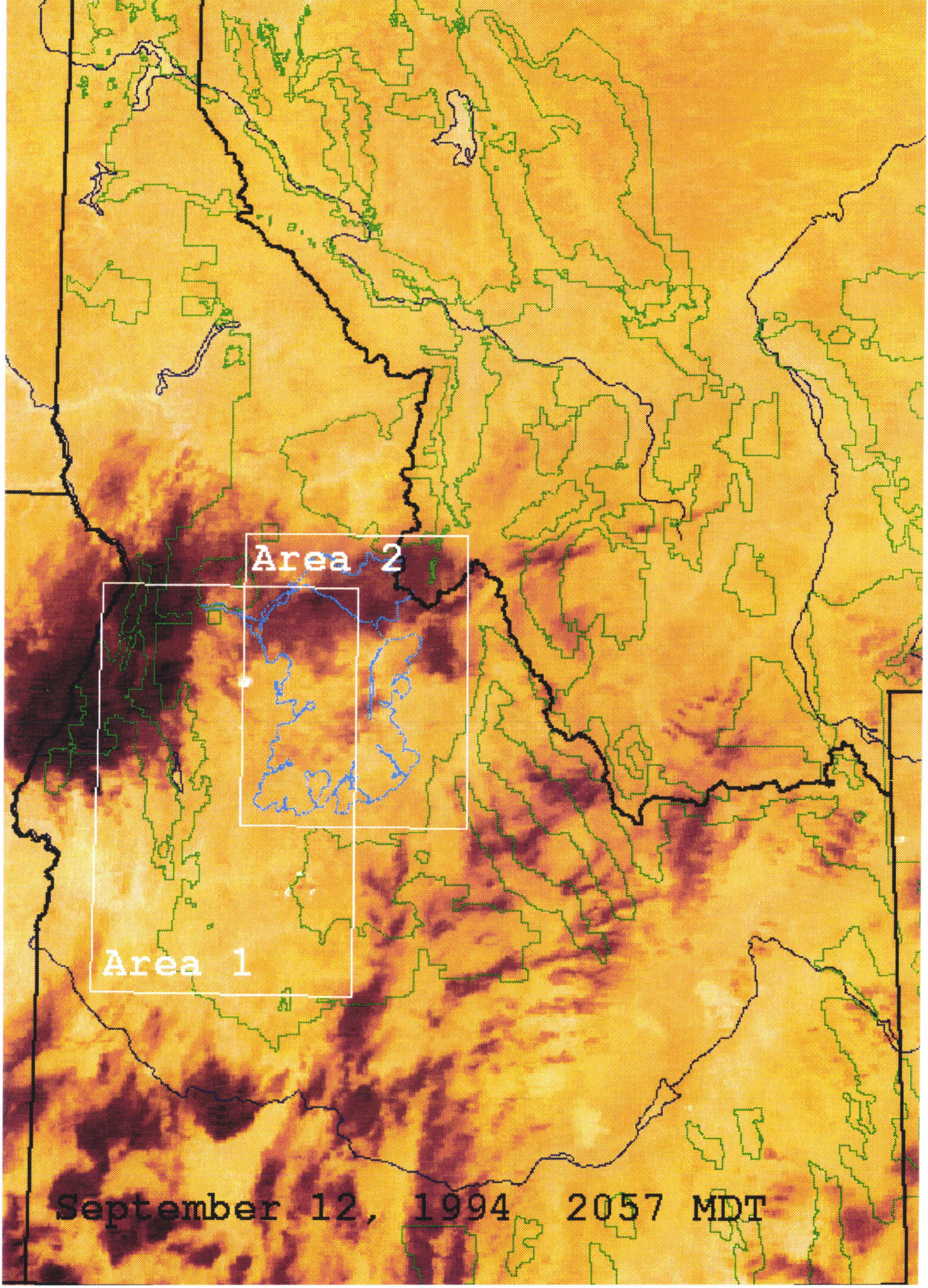

Corral
Complex
Chicken
Complex
Blackwell
Complex
Thunderbolt
Idaho City
Complex
116W
115W
45N
44N
August 28, 1994 1943 MDT


Area 2
Area 1
August 31, 1994 2016 MDT


Area 2
Area 1
September 4, 1994 1824 MDT


Corral
Complex
Chicken
Complex
Blackwell
Complex
45N
Thunderbolt
Idaho City
Complex
44N
Idaho Area 1
September 7 1994 2105 MDT


Area 2
Area 1
September 8, 1994 1736 MDT


Area 2
Area 1
September 12, 1994 2057 MDT

(2) Vector

Vector products were produced on the Arc-Info GIS system using the GRID and ARC PLOT modules. Following vectorization of individual fires, cumulative fire progression maps were produced by State or Region. Map scale is 1/2,500,000.

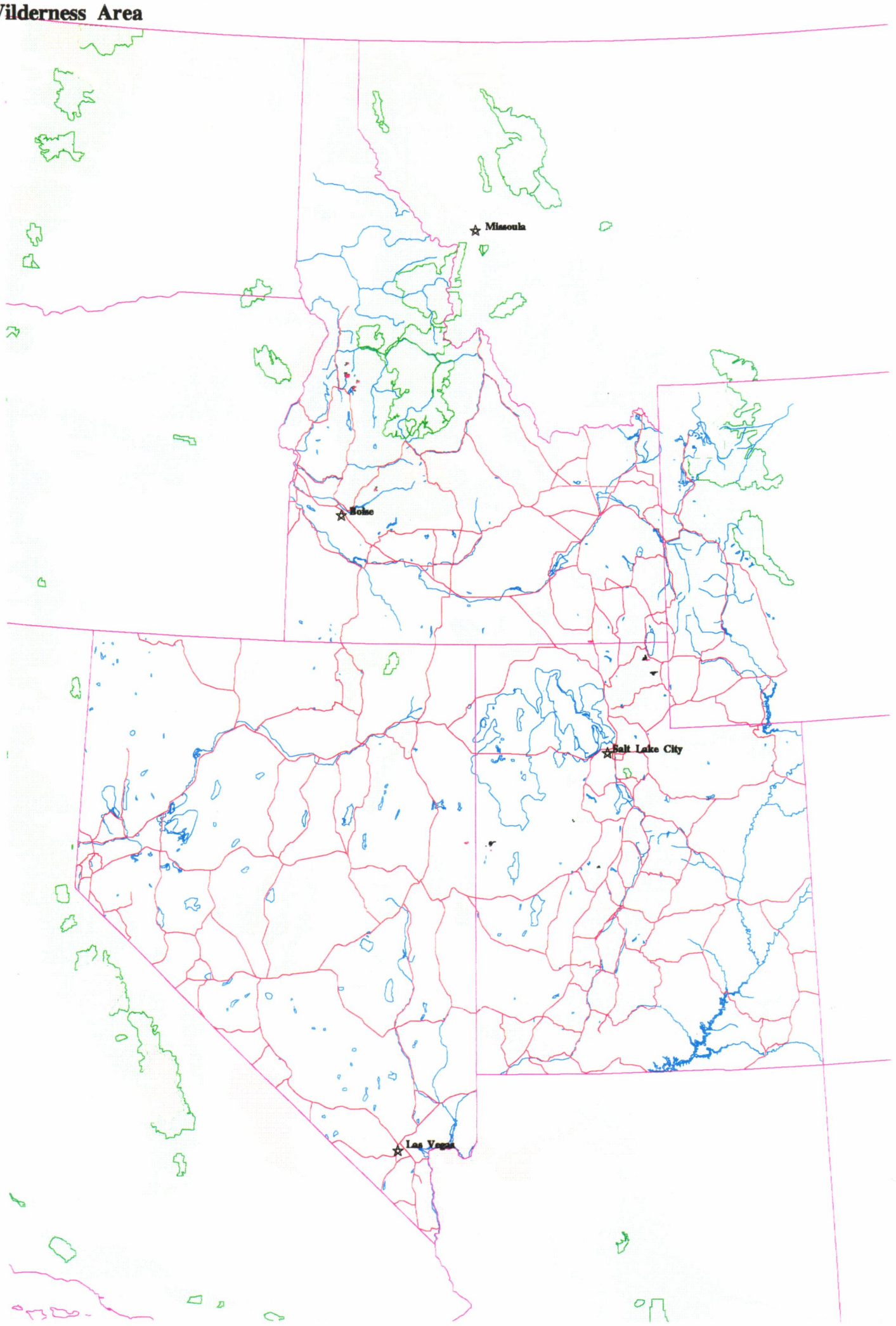
Map products produced at this scale covering several Forest Service Regions were printed at 33 inches x 51 inches size.

# US Department of Agriculture
# FOREST SERVICE
# Region Four

## Cumulative Fire Spread from Aug 5, 1994

## Date August 06, 1994
## Time 2057 MDT

- National Forest
- NRA or Natl Park
- Active Burning
- Previous Burn Area
- Lakes and Streams
- Main Roads
- State Boundary
- Wilderness Area



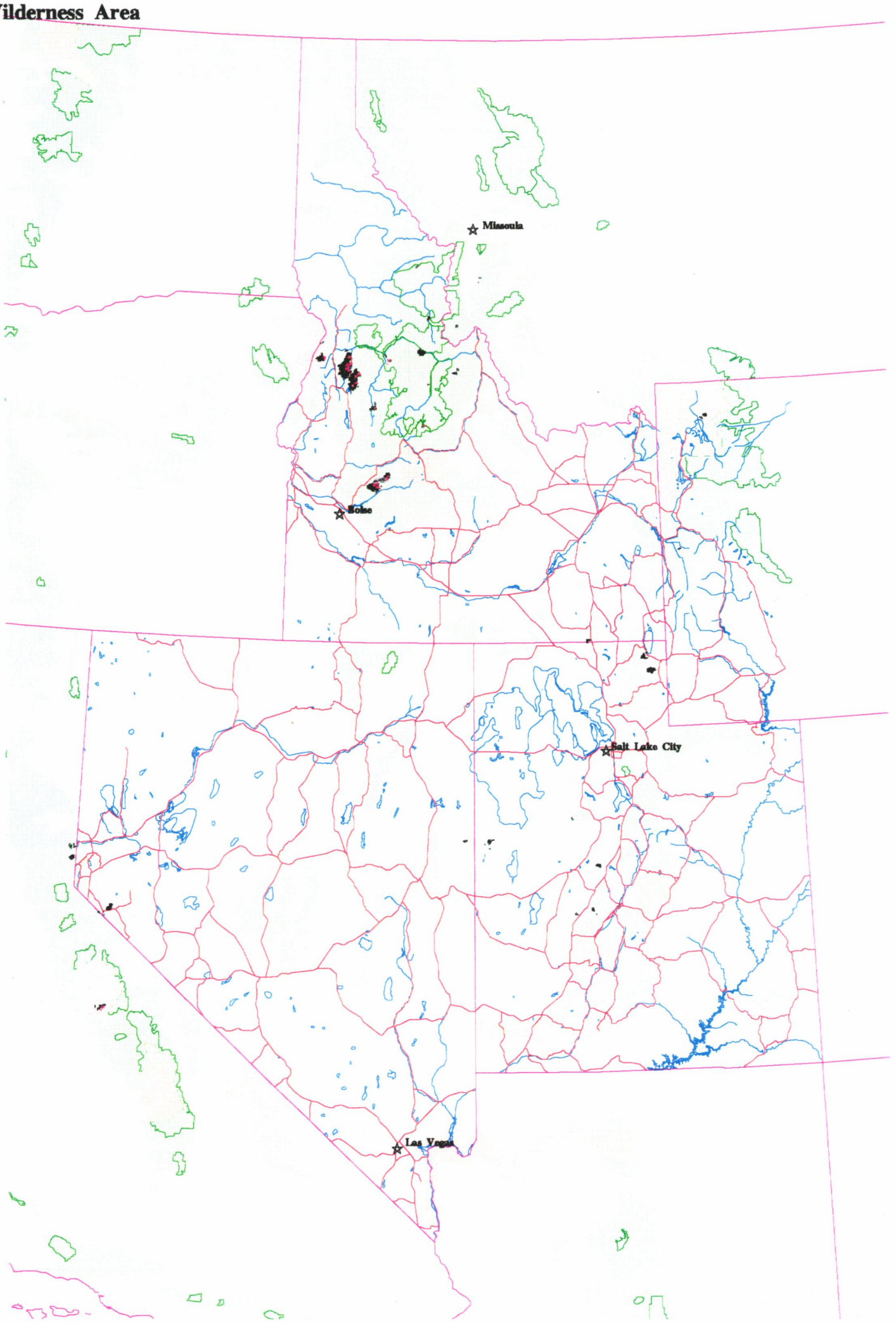

**Fires mapped using AVHRR Tyros Satellites (NOAA-11 & NOAA-12)**
**Data approximation varies from one to two kilometers.**

# US Department of Agriculture
# FOREST SERVICE
# Region Four

## Cumulative Fire Spread from Aug 5, 1994

## Date August 12, 1994
## Time 2027 MDT

National Forest
NRA or Natl Park
Active Burning
Previous Burn Area
Lakes and Streams
Main Roads
State Boundary
Wilderness Area



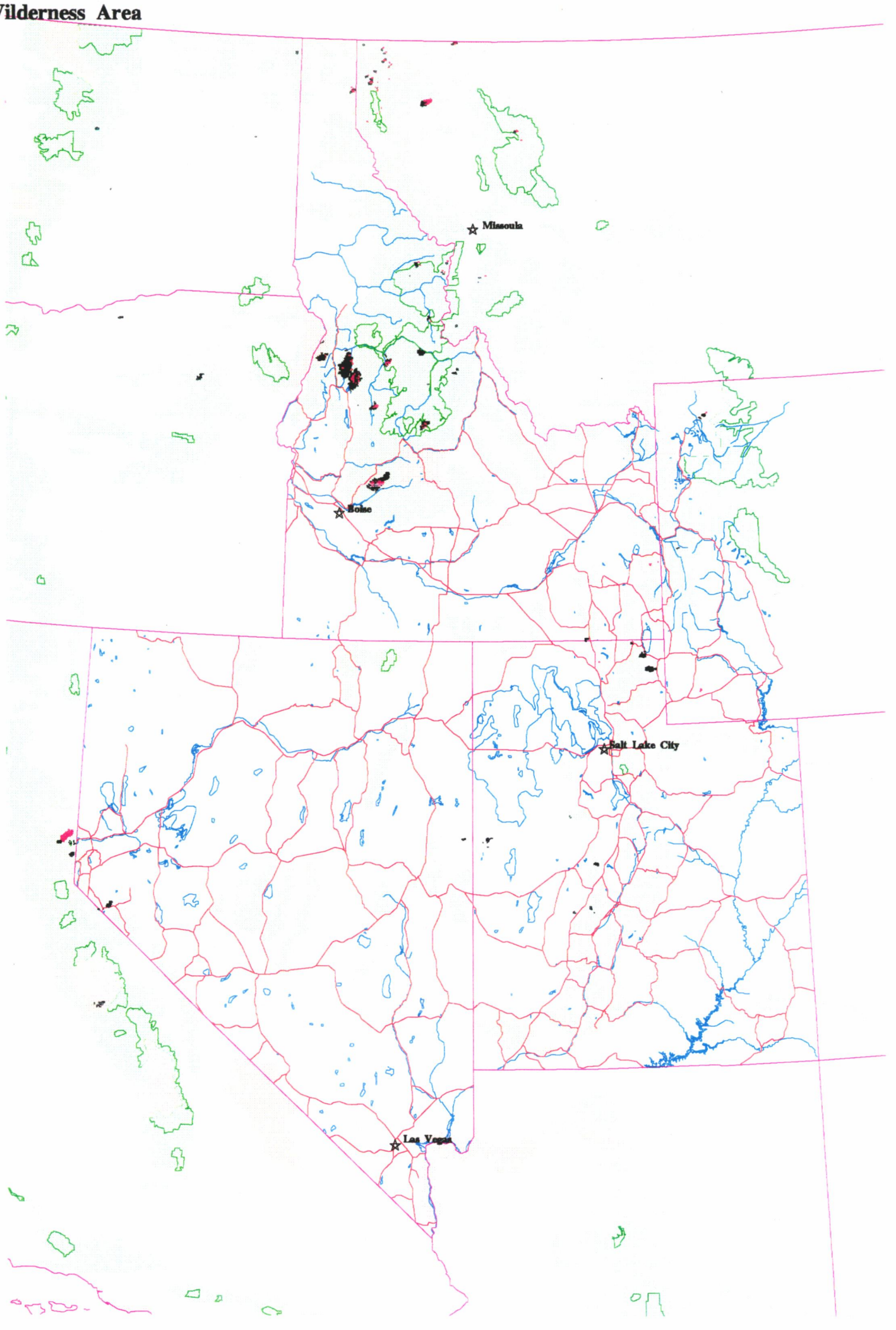

**Fires mapped using AVHRR Tyros Satellites (NOAA-11 & NOAA-12)**
**Data approximation varies from one to two kilometers.**

# US Department of Agriculture
# FOREST SERVICE
# Region Four

## Cumulative Fire Spread from Aug 5, 1994

## Date August 17, 1994
## Time 2019 MDT

- National Forest
- NRA or Natl Park
- Active Burning
- Previous Burn Area
- Lakes and Streams
- Main Roads
- State Boundary
- Wilderness Area



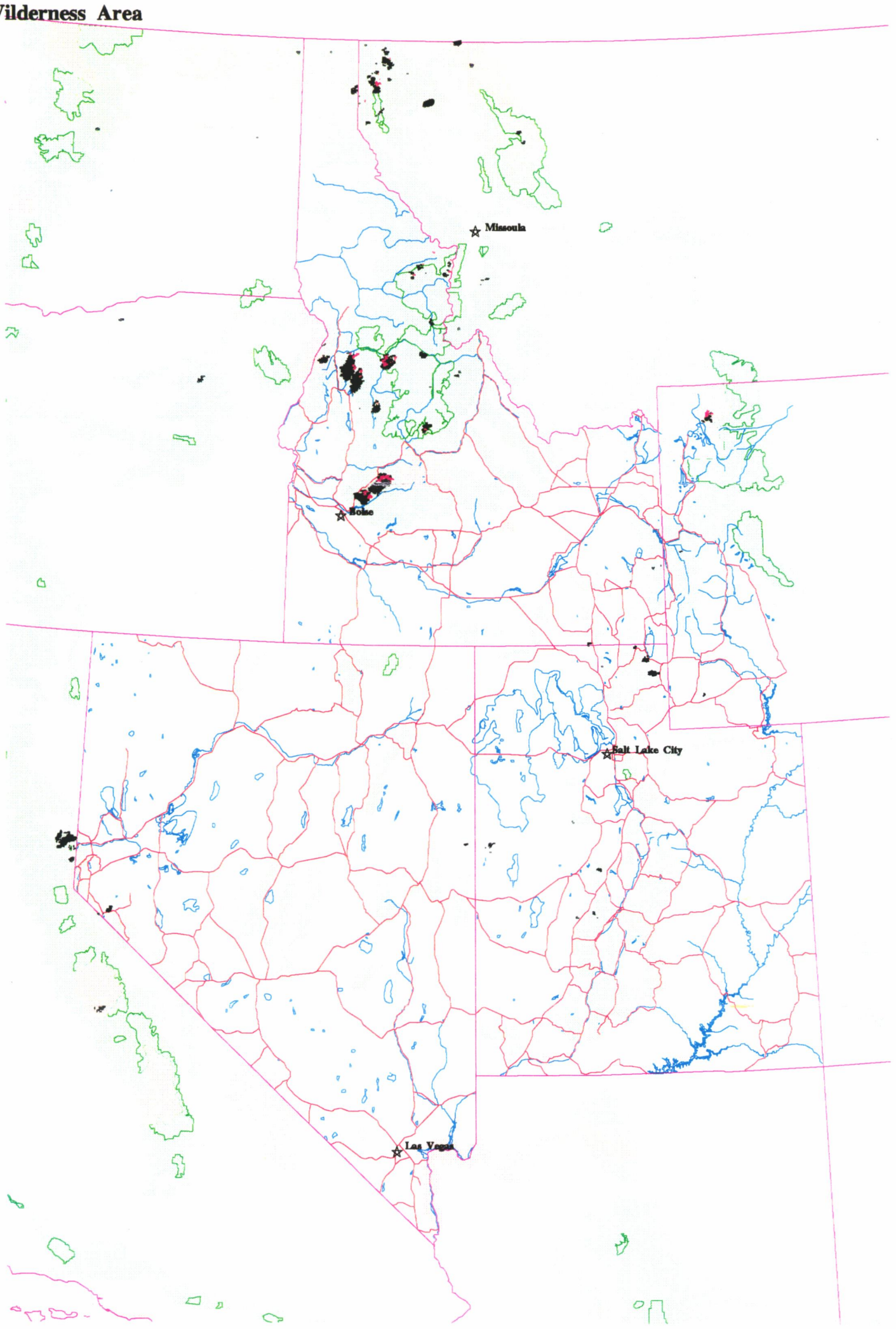

**Fires mapped using AVHRR Tyros Satellites (NOAA-11 & NOAA-12)**
**Data approximation varies from one to two kilometers.**

# US Department of Agriculture
# FOREST SERVICE
# Region Four

## Cumulative Fire Spread from Aug 5, 1994

## Date August 24, 1994
## Time 1719 MDT

- National Forest
- NRA or Natl Park
- Active Burning
- Previous Burn Area
- Lakes and Streams
- Main Roads
- State Boundary
- Wilderness Area



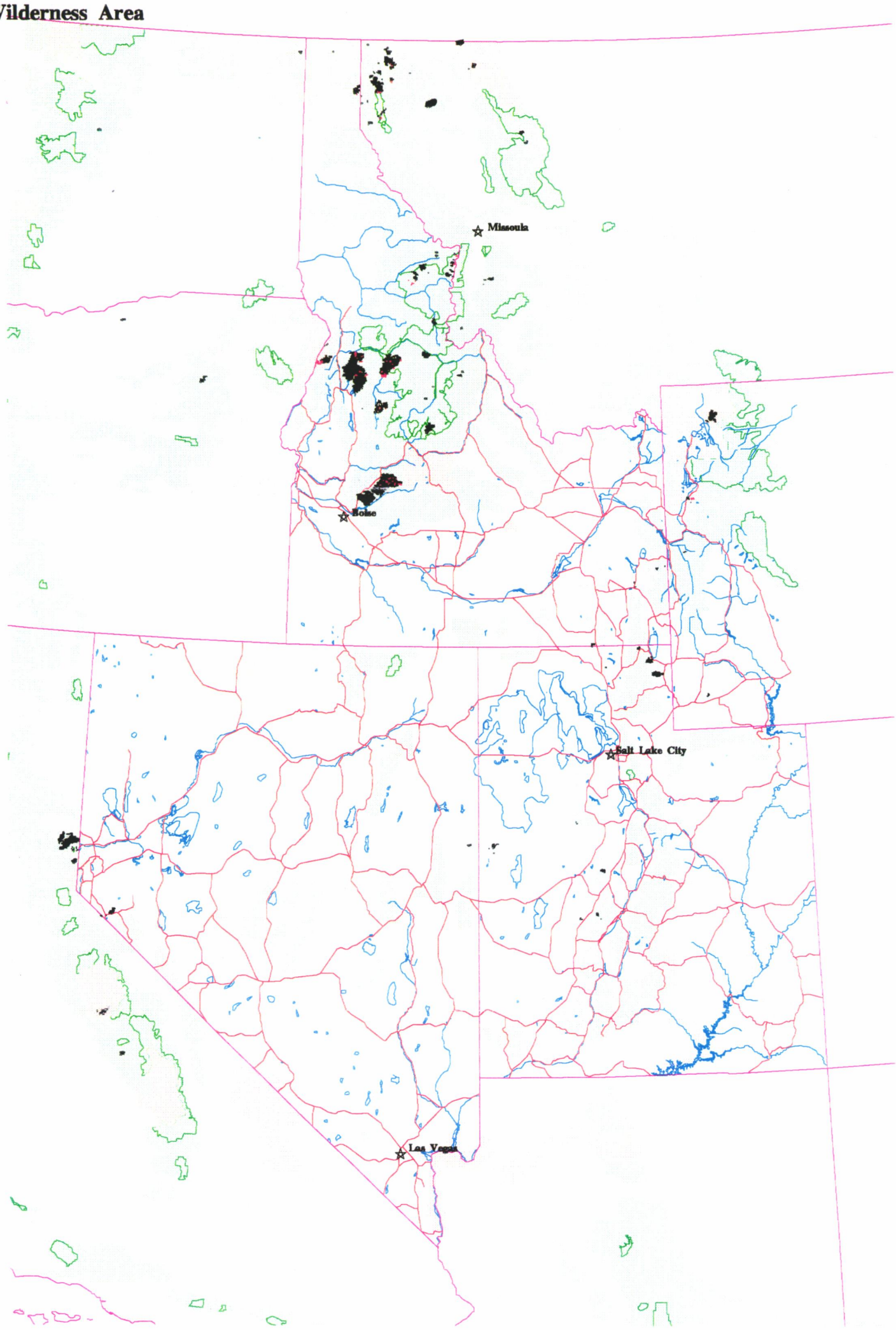

**Fires mapped using AVHRR Tyros Satellites (NOAA-11 & NOAA-12)**
**Data approximation varies from one to two kilometers.**

# US Department of Agriculture
# FOREST SERVICE
# Region Four

## Cumulative Fire Spread from Aug 5, 1994

## Date August 30, 1994
## Time 2038 MDT

- National Forest
- NRA or Natl Park
- Active Burning
- Previous Burn Area
- Lakes and Streams
- Main Roads
- State Boundary
- Wilderness Area



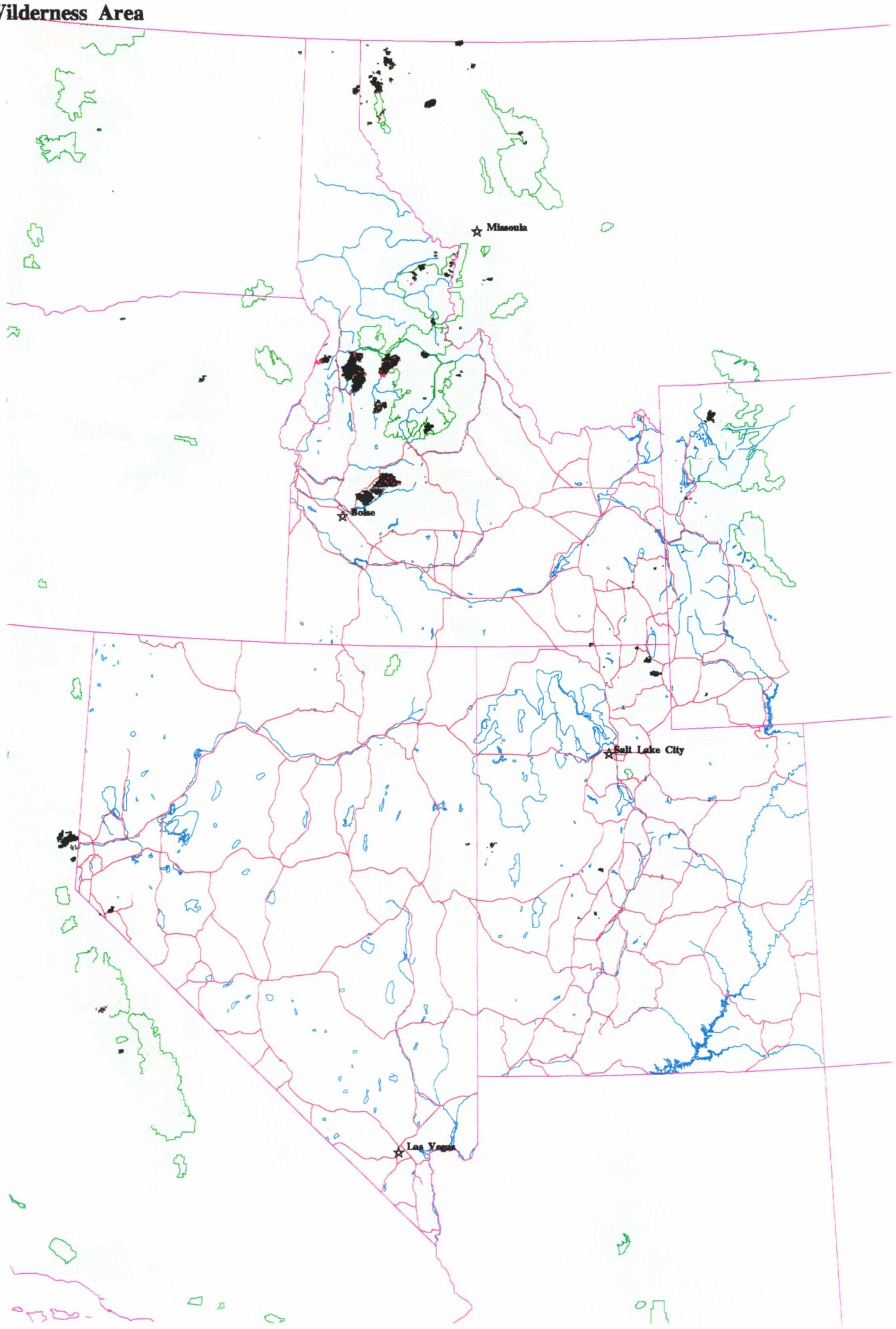

**Fires mapped using AVHRR Tyros Satellites (NOAA-11 & NOAA-12)**
**Data approximation varies from one to two kilometers.**

# US Department of Agriculture
# FOREST SERVICE
# Region Four

## Cumulative Fire Spread from Aug 5, 1994

## Date August 30, 1994
## Time 2038 MDT

- National Forest
- NRA or Natl Park
- Active Burning
- Previous Burn Area
- Lakes and Streams
- Main Roads
- State Boundary
- Wilderness Area



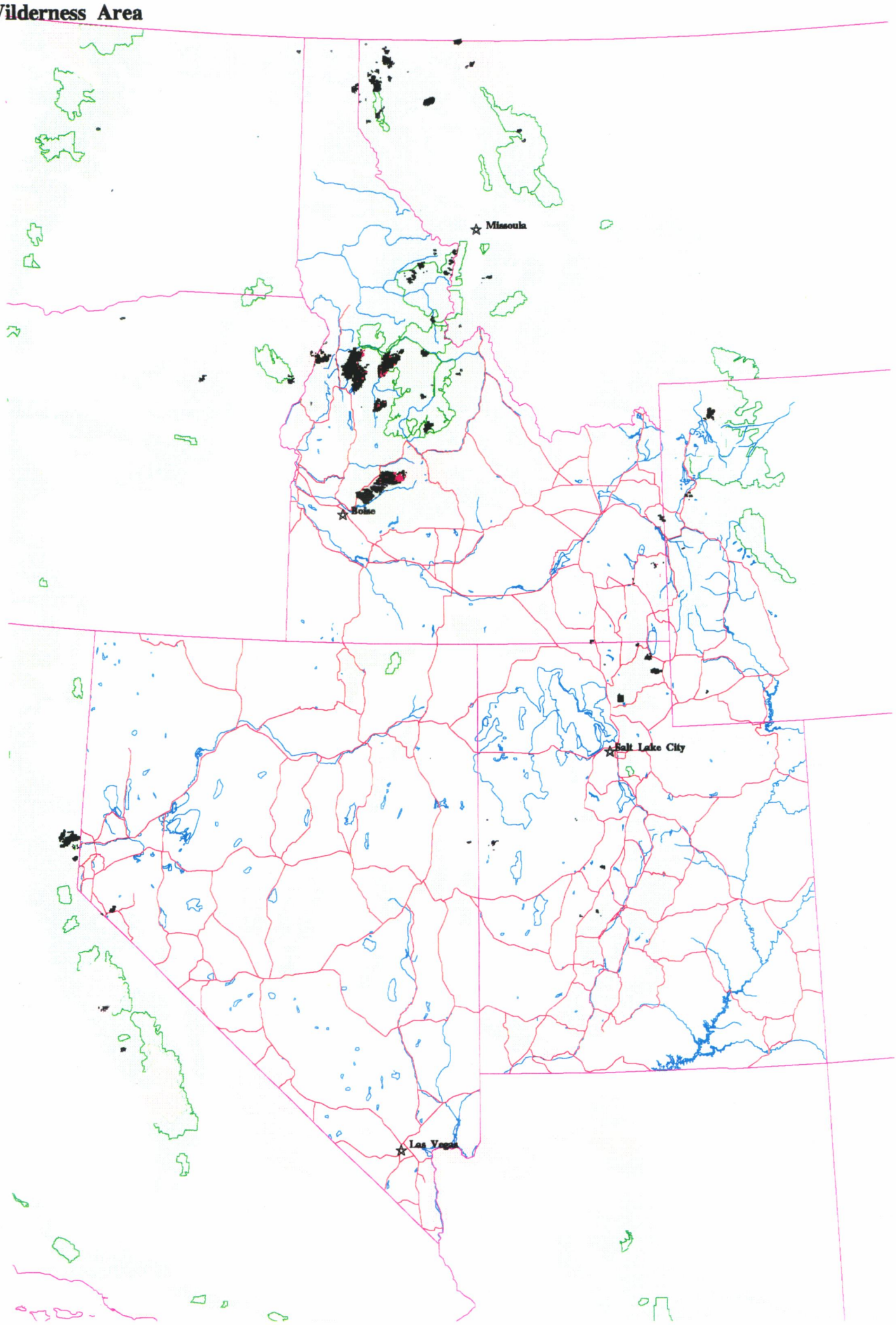

**Fires mapped using AVHRR Tyros Satellites (NOAA-11 & NOAA-12)**
**Data approximation varies from one to two kilometers.**

# US Department of Agriculture
# FOREST SERVICE
# Region Four

## Cumulative Fire Spread from Aug 5, 1994

## Date September 06, 1994
## Time 1800 MDT

- National Forest
- NRA or Natl Park
- Active Burning
- Previous Burn Area
- Lakes and Streams
- Main Roads
- State Boundary
- Wilderness Area



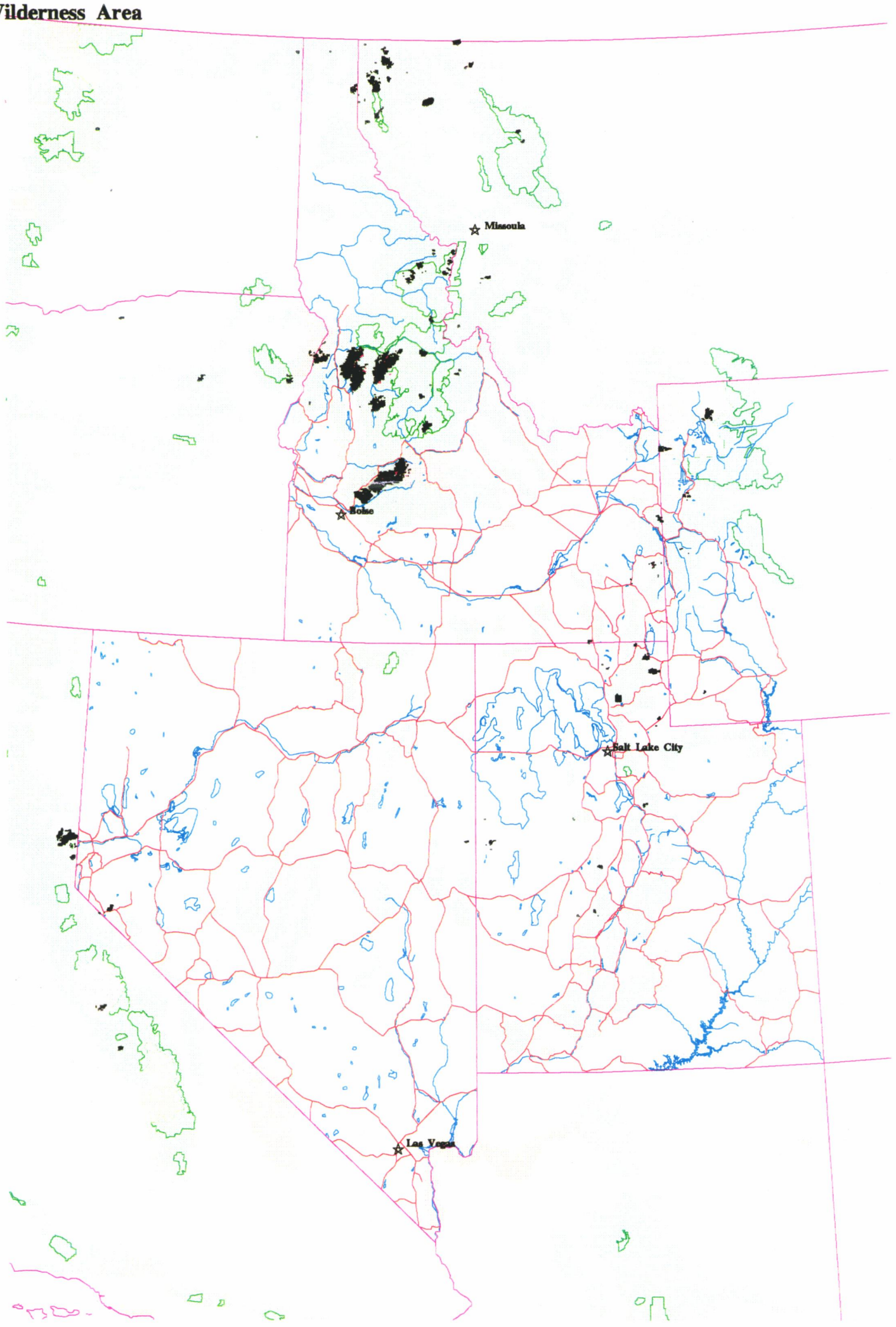

**Fires mapped using AVHRR Tyros Satellites (NOAA-11 & NOAA-12)**
**Data approximation varies from one to two kilometers.**

# US Department of Agriculture
# FOREST SERVICE
# Region Four

## Cumulative Fire Spread from Aug 5, 1994

## Date September 18, 1994
## Time 2027 MDT

- National Forest
- NRA or Natl Park
- Active Burning
- Previous Burn Area
- Lakes and Streams
- Main Roads
- State Boundary
- Wilderness Area




**Fires mapped using AVHRR Tyros Satellites (NOAA-11 & NOAA-12)**
**Data approximation varies from one to two kilometers.**

C. References

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